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PHYSICS.—*Incomplete equilibrium and temperature measurement.*

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ABSTRACT

The concept of temperature is discussed from the points of view of classical thermodynamics and statistical mechanics. The relation between relaxation phenomena and temperature measurement is explained, and several examples discussed qualitatively. Some methods for the measurement of temperature are examined in terms of the relation between relaxation and temperature. The methods considered cover several distinct types of situations encountered at high temperatures, and estimates are given of the reliability of the more modern methods.

INTRODUCTION

Interest in temperature and in its measurement is growing rapidly. This in large part is because of two recent trends. First, technology makes growing demands on scientific technique because of the high temperatures obtained in jet and rocket motors, and in nuclear devices. Second, progress in the statistical mechanics of non-equilibrium phenomena is opening new areas to scientific study. This article summarizes some aspects of the interplay of these trends. To do this we outline first the thermodynamic definition of temperature. Then we present the viewpoint of statistical mechanics, and last we apply this to a number of recent scientific and technical problems.

The detailed statistical mechanical theory requires considerable technical background, but it seems possible and desirable to bring the underlying ideas to a wide audience by discussing a number of recent applications of the theory to temperature measurements. The literature on the subject is very extensive, therefore we give chiefly references to review articles and symposia where the interested reader can find more details.

TEMPERATURE IN CLASSICAL THERMODYNAMICS

The problem of defining temperature is old and vexing. The usual procedure [*1*] starts with the notions "hotter" and "colder," assumes that they are given directly by experience, and does not attempt to define them. (Every logical system has primitive ideas which must be assumed without full definitions.) Two bodies are then said to be in thermal equilibrium if, when brought into close contact, they do not change their hotness or coldness. The so-called zeroth law of thermodynamics asserts that two bodies in thermal equilibrium with a third are in thermal equilibrium with each other. This permits one to choose a "standard body" and say that all bodies in thermal equilibrium with the standard have a particular property in common with it, namely the temperature. Some *empirical* temperature scale is then chosen, based, for example, on the thermal expansion of a metal or of a gas. The *thermodynamic* temperature scale is usually defined using an idealized steam engine running on a Carnot cycle. This steam engine and its cycle are a logical device for showing that the thermodynamic temperature is best considered the reciprocal integrating factor which changes the heat absorbed by the working gas in the engine, δQ (an *inexact* differential), into the *exact* differential dS, the entropy increase:

$$dS = \frac{1}{T}\delta Q. \qquad (1)$$

This approach can be generalized to any process and cycle, and makes possible a description of processes which does not depend on the paths taken but only on their end points.

The most rigorous discussion of temperature viewed as an integrating factor is due to Caratheodory [2]. His theory sheds much light on classical thermodynamics, but a description of it is out of place here.

The logically rigorous arguments establishing thermodynamic temperature apply to no *realizable* situations whatever because the temperature is defined only for *equilibrium* states and *reversible* processes. No actual system can be in perfect equilibrium, and every realizable process is irreversible. Many realizable systems are so close to equilibrium that ordinary thermodynamics can be used to calculate their properties. To find a justification for applying thermodynamics to real processes, and at the same time to explain why such application works so often, the viewpoint must be changed slightly, and in particular the notion of rates of processes must be introduced. The notion of rate is foreign to classical thermodynamics, but an examination of the concept of temperature in statistical mechanics will indicate how to use the results of thermodynamics.

TEMPERATURE IN STATISTICAL MECHANICS

Statistical mechanics studies systems which are composed of very many particles and have very many degrees of freedom. One gram of hydrogen gas at 0°C. and atmospheric pressure has approximately 18×10^{23} classical degrees of freedom. If one takes into account also the quantum degrees of freedom of the nuclear spin the total number is four times the above. Each state of each molecule has a characteristic total energy. Statistical mechanics shows [3] that, at equilibrium, the ratio of the average number N_i of molecules in the ith state, to the average number N_j in the jth state is given by

$$N_i = N_j e^{-W_{ij}/kT} \tag{2}$$

where W_{ij} is the difference in the energy of the states, k is the Boltzmann constant, and T the absolute temperature. The factor $e^{-W_{ij}/kT}$ is the Boltzmann factor, a distribution function giving the relative population of all the states of the system. This definition of T is fundamentally the same both in classical and quantum systems. In the classical case W_i can take on any value in a continuous range of numbers, and in the quantum case it can take only values from a set of discrete numbers. The simple arguments required to establish (2) apply again only to equilibrium systems.

Systems whose distribution functions differ from the Boltzmann type are the subject of irreversible statistical mechanics [4]. There it can be shown that systems whose distribution functions differ from the Boltzmann type change in such a way as to approach a Boltzmann distribution, in other words they approach equilibrium. If the initial departure from a Boltzmann distribution is not too great, then the differential equations which govern the changes in population may be fairly simple [5]:

$$\frac{dN_i}{dt} = f(N_i, N_{i\pm1}, \cdots) \tag{3}$$

where N_i is the population of the ith state. The function $f\ (N_i, N_{i\pm1}, \cdots)$ involves each population only to the first power if the system is sufficiently simple. Each N_i is multiplied by a characteristic rate constant which depends on the mechanism by which equilibrium is reached (such as collisions). For very simple systems these rate constants are related, and equation (3) can be rewritten:

$$\frac{dN_i}{dt} = \frac{1}{\tau}\sum_j a_j N_j \tag{4}$$

where τ is the so-called relaxation time, a constant which is characteristic of the system and gives the rate with which the system "relaxes" to the equilibrium distribution. A large τ means a slow approach to equilibrium. The sets of differential equations resulting from (4) can then be solved and the behavior of the system followed in time as it approaches equilibrium [6].

These ideas can now be applied to the study of temperatures. As an example consider a gas of atoms in a container, the whole immersed in a cool bath. Two rates will be important: First, the rate at which the gas would relax from a nonequilibrium distribution if the container walls were perfect insulators. The mechanism for this is the collision of the molecules, and τ_i is its relaxation time (i for internal). Second, the rate at which the container wall conducts heat away from the gas. Let this rate be characterized by a relaxation time τ_e (e for external). The actual changes in the system are then governed by the ratio τ_i/τ_e as well as by the initial conditions. If τ_i/τ_e is very small, the gas loses energy slowly through the walls but readjusts its distribution function continuously, which will then be practically of Boltzmann type, and at any one time the temperature of the gas will be a quite definite quantity which changes slowly in time because of the heat leak. This is the type of situation required for calorimetric work. If τ_i/τ_e is large, however, the heat leaks away faster than the gas can readjust. Temperature gradients are then set up in the gas, which start convection. The resulting complicated changes in the gas cannot be treated in detail by present statistical mechanical theory. In small portions of the gas, however, local equilibrium will exist, so that different portions of gas may have well-defined, though different, temperatures.

Or consider a solid at a temperature near 0°K. This solid consists of atoms which vibrate about their equilibrium positions (system A) and of the nuclear spins of the atoms (system B). Let the time for A to come to equilibrium with itself be τ_A, similarly for B, τ_B. Let the interaction of the systems be characterized by τ_{AB}, and let $\tau_B \ll \tau_{AB} \gg \tau_A$. Now remove some energy from the spin system B, say by isothermal magnetization followed by adiabatic demagnetization. Then the spins will come to equilibrium with each other very rapidly and their magnetic susceptibility will indicate a very low temperature. However, they interact so poorly with the lattice (τ_{AB} is large, of the order of hours) that the lattice temperature is essentially unaffected, and it makes sense to speak separately of a spin temperature T_S and a lattice temperature T_L, which are defined by equation (2) or by an analogous one.

Another type of example is afforded by a polyatomic gas in an ideally insulating enclosure. The motions of each molecule can be described to a good approximation by treating each type of degree of freedom separately, i.e., translation of the molecule as a whole, vibrations of the molecule, and its rotations. The total energy is the sum of the translational (W_t), the vibrational (W_v), and the rotational energy (W_r). The distribution functions may then be written [7]:

$$\left.\begin{aligned} N_{tvr} &= Ce^{-W/kT} \\ &= Ce^{-[W_t+W_v+W_r]/kT} \\ &= C(e^{-W_t/kT_t})(e^{-W_v/kT_v})(e^{-W_r/kT_r}). \end{aligned}\right\} \quad (5)$$

At equilibrium the same values of T will occur in each factor, *i.e.*, $T_t = T_v = T_r$. It happens, however, in many physical processes that one type of motion is affected more than another. For example, an ultrasonic wave passing through a gas may "heat up" the translations and rotations of the molecules without affecting the vibrations. It therefore becomes useful to inquire about relaxation times for distributing energy among the rotational motions, or for exchanging rotational and vibrational energy, and so on.

Many temperature measurement methods determine in effect a distribution function for a particular type of degree of freedom. Thus an important spectroscopic method [8] determines the relative populations of the different rotational states in the OH molecule. Only if τ_{rt} for this case is small will the distribution function indicate a unique rotational temperature T_r, and only if the exchange of rotational energy with the other forms of energy is rapid will this T_r indicate accurately an overall temperature.

To summarize: All temperatures actually measured are partial or effective temperatures. The custom of denoting partial temperatures with T^*, or "T", or $T_{\text{effective}}$ is therefore really redundant. These special notations serve, however, a very useful function by stressing the non-equilibrium

features of the system under study. Their use is therefore a matter of emphasis and convenience.

METHODS OF TEMPERATURE MEASUREMENT

We shall now indicate how these ideas have been applied to a variety of recent problems. All examples are from high temperature fields though the same fundamental considerations apply to all temperature regions.

1. *Temperature from the population of atomic levels.* It is possible to introduce small amounts of metal vapor into hot gases by adding, for example, Na salts, Cu salts, or Fe carbonyl. The metal atoms interact with the species in the gas and may come to thermal equilibrium with the gas. Excited states of the metal atoms will then become populated in accordance with the Boltzmann factor. The atoms will return to their ground states or other lower states by radiation, and the relative intensities of the lines emitted can be used to estimate the relative populations of the levels involved, and hence the temperature of the atoms. If adequate equilibrium obtains, the method can be very useful. The method requires knowledge of the optical transition probabilities of the metal atom. The detailed conditions for a successful application of the method are described by Sobolev [*9*], who measured flame temperatures of about 3,000°K. with an estimated uncertainty of about 1.3 per cent.

In many experimental situations it is unlikely that adequate equilibrium is obtained. In fact it may happen that this method measures some T^* of the system reliably because the atomic populations may come to equilibrium with some degrees of freedom of the system but not the others. Gaydon [*10*] mentions circumstances where atomic excitation measures T_{vibr} of some molecular species in a flame.

The method has to be carefully checked before its results can be accepted, particularly when applied to systems undergoing chemical reactions. This is because unstable chemical species which occur as intermediates of chemical reactions often excite some atoms with preference into certain levels, and so produce distributions which are far removed from equilibrium [*11*]. In such cases the method is not reliable at present.

2. *Temperature from Doppler line width.* The motion of a molecule along the line of observation while it radiates shifts the wave lengths at which the radiation is observed relative to the wave lengths observed for a stationary molecule. This effect, known as the Doppler effect, broadens the spectral lines which are observed, and gives the lines a characteristic shape [*12*]. This provides a method useful in principle for measuring the velocity distribution (hence the translational energy distribution) of the molecules. The method does not require any knowledge of the molecular or atomic structure of the species beyond knowledge of molecular or atomic weight. With it the translational temperature of CH in a low pressure flame was found to be about 3,500°K $\pm$ 600°K., an uncertainty of about 20 per cent [*13*].

The method is not accurate. The main difficulty is that Doppler broadening is a small effect and may be masked by other effects such as collision broadening. To use the method fully, equipment of the highest resolving power should be used. When this is done, the whole contour of the spectral line can be determined. This allows one to infer the actual existing velocity distribution, if other effects on the line shape can either be ignored or taken into account.

3. *Temperature from vibrational spectra.* In systems in equilibrium the vibrational degrees of freedom of gas molecules are in equilibrium with each other and with the rest of the system. Therefore the relative populations of the vibrational levels are given by the Boltzmann factor, and a measurement of relative intensities of spectral lines associated with different vibrational levels will allow a determination of the temperature [*14*]. In other cases the vibrational degrees of freedom may be in equilibrium with each other without being in equilibrium with the rest of the system. In such cases a determination of relative populations of vibrational levels allows a determination of T_{vibr}.

Several types of methods are in use. In one method the emission of radiation from a

complete *unresolved* vibration-rotation band is compared with the emission from a standard source [*15*]. The method is said to be good to about 2.5 per cent near 2000°K.

Another method consists of measuring the relative intensities of emission lines belonging to the same rotational levels of different vibrational levels [*16*]. Experimental uncertainties are said to be about 10 per cent of T_{vib} near 2,500°K.

Both methods require directly the quantum mechanical transition probabilities. These are difficult to calculate, though they have been obtained for OH [*17*], C_2 [*18*], and a few other molecules. In general these transition probabilities must be obtained from experiment when the species are known to be in equilibrium at a given temperature. Once they are known, they can be applied to calculations of nonequilibrium or partial equilibrium situations.

A thorough discussion of these methods and some variations is given by Smit [*19*].

4. *Temperature from rotational spectra.* Several methods are currently used to determine temperature from rotational spectra. Most of these depend on the comparison of relative intensities of rotational lines and on the relative populations inferred from the intensities [*8*].

Thorough reviews of methods based on rotational spectra have been given by Dieke and coworkers [*20*].

The relative transition probabilities are required for this method. They can be calculated with good accuracy for many diatomic molecules and can be determined experimentally for cases where calculations are difficult.

Several distinct ways are used to calculate temperatures from intensities. We do not give the details of these methods. The two most common methods are the "log intensity" method and the "iso-intensity" method [*20*]. If the observed lines are absorbed strongly the data may give fictitious indications of non-equilibrium population of levels. A recent method by Kostkowski and Broida [*21*] makes possible the determination of reliable temperatures even in the case of large absorption.

The experimental uncertainties in the determined temperatures vary greatly from one case to another. Uncertainties as small as 1% at 3000°K have been reported, while attempts have been made to apply the method where uncertainties are close to 100 per cent [*11*].

5. *Temperature from optical pyrometers.* This method consists of comparing the brightness of the object whose temperature is to be measured with that of a standard whose brightness is known from calibration as a function of temperature. Two main variations are in use: one-color pyrometry where brightness is compared at one wavelength, and 2-color pyrometry where brightness is compared at two wavelengths. If the system to be studied is in internal equilibrium, and if its emissivity is known at the wavelengths of comparison, then either method is reliable and gives good values of T. In practice neither of these two conditions is likely to be fulfilled.

In flames the continuous radiation emitted which is usually used in pyrometer methods comes from small incandescent solid particles of carbon. Recent studies [*22*] have shown that these carbon particles are in equilibrium with the surrounding gas. The carbon particles, however, are so small (about one wavelength of visible light in diameter) that their size strongly affects their optical properties. To determine flame temperatures accurately using this method, the effect of particle size must be taken into account. In some cases, temperatures obtained with pyrometers from carbon particles in flames have been found to agree well with temperatures from line reversal techniques [*23*]. In other cases comparisons have been worked out between such pyrometrically measured temperatures and blackbody temperatures [*24*].

Pyrometric methods are particularly useful as empirical control devices when no explicit correlation can be made between the measurement and an equilibrium temperature. If, e.g., the emissivity of the system is unknown, or if no partial equilibrium can be found in the system, then the pyrometer can be used to good advantage as a control device. In many industrial applications of pyrometry this is the exact attitude adopted.

6. *Temperatures from thermocouples.* Ther-

mocouples measure temperature by generating an e.m.f. across their open terminals when the measuring junction is at a different temperature than the reference junction. The generated e.m.f. is a function of the temperature, therefore a calibration must be available covering the whole temperature range to be measured [25].

Two problems of thermocouple construction and use are of particular relevance to our present point of view. One arises in the measurement of the temperatures of hot gases through a container wall, and the problem is to have the thermocouple follow temperature changes in the gas rapidly. For metal walls this does not seem to be too difficult. For plastic or refractory walls a large time lag may be introduced by the poor thermal conductivity of the wall material. However, special methods of design have been found which make possible adequate heat contact between the thermocouple in the wall and the gas [26].

A second application of thermocouples where the approach to equilibrium is a significant problem is the measurement of temperatures of gases having large bulk flow velocities, such as in super- and hypersonic wind-tunnels, in exhausts of jets, etc. A problem here is to devise an arrangement of the thermocouple which measures the stagnation temperature of the gas. This means that a sample of the gas must be stopped rapidly enough to be sensibly adiabatic, yet slowly enough for the gas to come to internal equilibrium. The thermocouple is then exposed to the gas sample just prepared. A thorough survey of such devices is given by Eber [26]. Well-designed thermocouple probes have recovery factors of about 0.95 which are furthermore independent of Mach number in the range of stream velocity employed. (The recovery factor is the fraction of the theoretical temperature rise on stagnation, which can be accomplished experimentally.)

With suitable construction and calibration equilibrium temperatures can be measured. But even in the absence of calibration, and with poor design, thermocouple probes can be used as empirical control devices.

7. *Temperature from the velocity of sound.* The velocity of sound through any medium is a function of temperature. Therefore the velocity of sound may be used to measure the temperature. The method is particularly useful in gases and can be used under conditions where many other methods fail or are inconvenient [27, 28, 29]. The velocity of sound in a gas is a function not only of the temperature, but also of $\gamma = C_p/C_v$ and of the molecular weight of the gas. This puts a number of restrictions on the method. At high frequencies of sound γ appears to change because the molecules cannot come to equilibrium in the time of one period of the sound wave if the frequency is too high. Furthermore, if the gas is not in equilibrium the value of γ may depend on the details of the processes in the system in a complicated way. Therefore the theory of the propagation of sound in a non-equilibrium gas is complicated. The measured velocity of sound is an average velocity averaged over all the gas in the path of the sound wave. If strong local temperature variations are to be expected the method loses some of its power. Under circumstances where the gas is not homogeneous and is not in well-defined partial equilibria with respect to some of the important processes, the method can at present only be used as a control device.

An alternative method involves the measurement of the velocity of shock waves through gases. The shock waves are generated by a spark and their velocity determined by a photographic method. This method is subject to the same types of limitations mentioned above, except that a photographic method may enable one to determine *local* velocities instead of one single average velocity as above.

8. *Control devices and further progress.* Many systems encountered in technology are so complex that very little can be said about relaxation times and about partial equilibrium. It is then difficult to define temperature, but it is important to realize that even in extremely complex situations measurement gives *some* information. For example, the transit time of an ultrasonic wave in the exhaust gases of a jet engine does give an indication of the state of the gases. It gives, however, only one "bit of information," while perhaps several hundered bits would be required to describe the system.

Thus it is futile to hope that the one observed bit will adequately specify all the variables. The most fruitful approach would seem to be the selection of several quite distinct temperature measurement methods which are reasonably easy to use under the circumstances: say, pyrometer, spectral-line reversal, and transit time of ultrasound, giving three independent control parameters. While none of these will, strictly speaking, measure temperatures, they will specify several different properties of the system. In this way a fairly thorough control of the system should be possible, and the dependence of the control parameters on experimental conditions would guide further experimentation. At the same time experience is gained in the study of really complex systems, and thus the groundwork laid for further advances in the fundamental understanding of nonequilibrium processes. This in turn will make possible the further extension of the concept of temperature.

REFERENCES

[1] ZEMANSKI, M. W. *Heat and thermodynamics*, 3d ed. New York, 1951.

[2] CHANDRASEKHAR, S. *Introduction to the study of stellar structure*, chapter 1. Chicago, 1939.
MARGENAU, H., and MURPHY, G. M. *The mathematics of physics and chemistry*, chapters 1 and 2. New York, 1943.

[3] TOLMAN, R. C. *The principles of statistical mechanics*. Oxford, 1938.

[4] MONTROLL, E. W., and GREEN, M. S. *Statistical mechanics of transport and non-equilibrium processes*. Ann. Rev. Phys. Chem. **5**. 1954.

[5] HERZFELD, K. F. *Relaxation of partial temperatures. Temperature, its measurement and control in science and industry*, **2**. New York, 1955. (This volume will be referred to hereafter as "Temperature **2**.")

[6] RUBIN, R. J., and SHULER, K. E. Journ. Chem. Phys. **25**: 59. 1956.

[7] SHULER, K. E. Journ. Chem. Phys. **18**: 1466. 1950.

[8] BROIDA, H. P. *Temperature measurements in flames and hot gases*. Temperature **2**.

[9] SOBOLEV, N. N. Journ. Exp. Theor. Phys. USSR **19**: 25–35. 1949.

[10] GAYDON, A. G. *Energy transfer in hot gases*. NBS Circular 523. 1954.

[11] THOMAS, N. *Section N, Physical measurements in gas dynamics and combustion*, Editors: R. W. Ladenburg, B. Lewis, R. N. Pease, H. S. Taylor. High Speed Aerodynamics and Jet Propulsion **9**. Princeton, 1954. (Hereafter called "High Speed **9**.")

[12] WHITE, H. E. *Introduction to atomic spectra*, chapter 21. New York, 1934.

[13] GAYDON, A. G. and WOLFHARD, H. G. Proc. Roy. Soc. London **199A**: 89. 1949.

[14] HERZBERG, G. *Spectra of Diatomic Molecules*, chapter 3. New York, 1950.

[15] SILVERMAN, S. *Third combustion symposium*. 498. Baltimore, 1949.

[16] SILVERMAN, S. *Energy transfer in hot gases*. NBS Circular 523. 1954.

[17] SHULER, K. E. Journ. Chem. Phys. **18**: 1221. 1950.

[18] McKELLAR, A. and BUSCOMBE, W. Publ. Domin. Astrophys. Observ. Victoria, B. C., **7**: 361. 1948.
McKELLAR, A. and TAWDE, N. R. Astrophys. Journ. **113**: 440. 1951.
TAWDE, N. R. and PATEL, J. M. Astrophys. Journ. **112**: 210, 1951.
BATES, D. R. Monthly Notices Roy. Astron. Soc. **112**: 614. 1952.

[19] SMIT, J. A. *The production and measurement of constant high temperatures, up to 7000°K*. Dissertation. Utrecht, Netherlands, 1950.

[20] DIEKE, G. H. Section M, High Speed **9**.
DIEKE, G. H. and CROSSWHITE, H. M. *Energy transfer in hot gases*. NBS Circular 523. 1954.

[21] KOSTKOWSKI, H. J. and BROIDA, H. P. Journ. Optical Soc. Amer. **46**: 246. 1956.

[22] SHULER, K. E. Mem. Soc. Roy. Sci. Liége, 4th series **15**: 360. 1954.

[23] BARRET, P. Publ. Sci. et Techn. Minist. Air, no. **273**: 114. 1952.

[24] NAESER, G. and PEPPERHOFF, W. Arch. Eisenhüttenwesen **22**: 9. 1951.
REID, W. T. Section J, High Speed **9**.

[25] BAKER, H. D., RYDER, E. A. and BAKER, N. H. *Temperature measurement in engineering* **1**. New York, 1953.

[26] EBER, G. Section D, High Speed **9**.

[27] BUNDY, F. P. and STRONG, H. M. Section I.7, High Speed **9**.

[28] CADY, W. M. Section D.3, High Speed **9**.

[29] HEDRICH, A. L. and PARDUE, D. R. Temperature **2**.

ENTOMOLOGY.—*Type specimens of mosquitoes in the United States National Museum: III, The genera* Anopheles *and* Chagasia (*Diptera, Culicidae*).[1]

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The introductory remarks in the first paper of this series, particularly those on early, possibly questionable holotypes, also apply to this one. Following our treatment of nominal taxa requiring special attention we present a list of those in the collection based on unique specimens or for which holotypes were clearly designated.

Genus **Anopheles** Meigen

Anopheles apicimacula Dyar and Knab, Proc. Biol. Soc. Washington **19:** 136. 1906.

Of the 26 original specimens of this species, 22 are in the collection. One female only, from Livingston, Guatemala, May 11, bears a type label, and this we consider the holotype. This specimen was designated as lectotype in Russell, Rozeboom, and Stone (1943, p. 31) although we now feel that this lectotype designation was not necessary, as explained in the introduction to this series.

Anopheles atropos Dyar and Knab, Proc. Biol. Soc. Washington **19:** 160. 1906.

The syntype series of this species consisted of seven female specimens from the Florida Keys, collected by H. Byrd. All these are in the collection and all are labeled "Type No. 10029 U.S. N.M." We select as lectotype one of the best of these specimens.

Anopheles (*Kerteszia*) *bambusicolus* Komp, Ann. Ent. Soc. Amer. **30:** 515. 1937.

The syntype series of this species consisted of three females with associated larval skins. These specimens stand in the collection all bearing the labels "La Union, Int. de Meta, Colombia, Sept. 1935. Jorg Boshell / On bamboo / Cotype No. 53075." There are four larval skins on slides, but since the pinned specimens are not numbered these skins cannot be associated with individual specimens. Two of the pinned specimens are *Anopheles bambusicolus* Komp, and we select the better one as lectotype. The third is a specimen of *Culex chryselatus* Dyar and Knab and has been transferred to that species in the collection.

Anopheles barberi Coquillett, Can. Ent. **35:** 310. 1903.

This species was described from three females collected on Plummers Island, Md., August 14, 1902, and August 17 and 19, 1903. Only one of these specimens, dated August 17, is in the collection, and it bears the type label and Coquillett's determination label. We consider this specimen to be the holotype.

Anopheles bellator Dyar and Knab, Proc. Biol. Soc. Washington **19:** 160. 1906.

The original three specimens of this species are in the collection, consisting of one male and two females, all labeled "Type No. 10027 U.S.N.M." We select as lectotype the male labeled "44.1 / Trinidad, W.I. Jan. / Aug. Busck Collector / See slide No. 314 / Slide #659 / bellator." The terminalia are on slide no. 314, and one front tarsus is on slide no. 659. The pupal skin from which this specimen came has also been mounted on a slide.

Anopheles (*Dendropaedium*) *bellator* race *bromelicola* Dyar and Knab, Ins. Insc. Mens. **13:** 27. 1925.

The two female syntypes of this, from Manoa, Orinoca River, Venezuela, are in the collection, each bearing only the labels "Manoa Woods Jan 10 / Type No. —— U.S.N.M." We select one of these as lectotype.

[1] Earlier papers in this series are: *I, The genera* Armigeres, Psorophora, *and* Haemagogus, Journ. Washington Acad. Sci. **45:** 282–289. 1955; *II, The genus* Aedes, *ibid.* **46:** 213–228. 1956.

[2] Studies upon which this paper is based were conducted under an exchange of funds from the Office of Naval Research (Biological Science Division) to the Smithsonian Institution. The opinions or assertions contained here are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large.

Anopheles (*Anopheles*) *chiriquiensis* Komp, Proc. Ent. Soc. Washington **38:** 156. 1936.

Both sexes and the larva of this species were originally described, but no type material was mentioned. The collection contains one male and one female labeled "Anopheles chiriquiensis Komp / Volcan de Chiriqui, Panamá II.7.35 6500 ft / Cotype No. 51882 U.S.N.M. / W.H.W. Komp." The male is labeled #1, and this has dissected terminalia mounted on a slide. There is a second female of the original material, not labeled as cotype, and one larval skin, not associated by label with any specific adult. We select the male as lectotype.

Anopheles (*Nyssorhynchus*) *darlingi* Root, Amer. Journ. Hyg. **6:** 706. 1926.

The lectotype male of this species, selected by Stone in Ross and Roberts (1943, p. 30), is in the collection.

Anopheles (*Nyssorhynchus*) *davisi* Paterson and Shannon, Terc. Reun. Soc. Arg. Mosq. de Embarcación: 5. 1927.

This species was described from 6 larvae, 50 females, and 2 males from Trez Pozos, Embarcación, Salta, Argentina. The collection contains a larval slide and two male terminalia slides bearing the original data, and four pinned females collected at the proper time but at Bella Vista, Embarcación, not Trez Pozos. The larva and one of the male slides were labeled "Type" by Shannon, but the adults from which the male terminalia came are not in the collection. There is no indication in the original publication as to where the types were to be deposited, and it is quite possible that there are more and better specimens of the syntype series in Argentina. Because of this, it seems advisable to defer selection of a lectotype.

Anopheles (*Nyssorhynchus*) *dunhami* Causey, Journ. Nat. Malaria Soc. **4:** 231–234. 1945.

The original description of this species states, "The type specimens have been forwarded to the National Museum in Washington, D. C." There is no statement as to the number of specimens involved, although the species was collected in large numbers on animal bait in Tefé, Amazonas, Brazil, and the female, male, egg, and larva are described. The collection contains a male labeled type and a female labeled paratype, both reared from eggs laid by a female collected in Tefé, Amazonas, Brazil. We consider this male, with terminalia mounted on a slide, to be the holotype.

Anopheles earlei Vargas, Bol. Ofic. Sanit. Panamericana **22:** 8. 1943.

The original description of this species designated a male holotype with the dissected terminalia mounted on two slides and a female allotype. The type locality was given as being Jefferson County, Wis. The type was collected July 10, the allotype July 13. These specimens are in the collection bearing these data. For this reason the statement in Vargas and Matheson (1948, p. 27) that "El tipo macho fue de Cayuta Lake, Nueva York" is erroneous.

Anopheles eiseni Coquillett, Journ. New York Ent. Soc. **10:** 192. 1902.

This species was described from one female and two males. Two of the original specimens are in the collection, one of the males not being found. The female only bears a type label and it also bears Coquillett's determination label. This specimen we consider to be the holotype.

Cellia flava Ludlow, Can. Ent. **40:** 32. 1908.

This species was described from four specimens, which are in the collection, bearing unnumbered type labels. These specimens are all females, although the original description includes both sexes. We select as lectotype the specimen bearing the label "Cellia flava Ludl. Type" and some indecipherable words. There are other specimens from Tayabas, the type locality, including males, that might have been before Ludlow when she described the species.

Myzomyia flavirostris Ludlow, Psyche **21:** 30. 1914.

It is not clear from the original description that this species was based on more than one specimen, but the collection has four females bearing unnumbered type labels. Only one has an additional label, as follows: "*M. funesta* Giles dark *flavirostris*. Camp Wilhelm, Tayabas, P. I. Type. Nov." The word "*flavirostris*" is written in pencil, and the word "Type" is apparently written with a different pen from the rest of the label. This specimen is the best of the four and we select it as lectotype.

Anopheles formosus Ludlow, Can. Ent. **41:** 22. 1909.

This species was presumably described from a single female, but it is not clearly so stated in the original description. We consider the single female, with the labels "Type No. 27781 U.S. N.M. / Anopheles formosus Ludl. Type C.S.L. Camp John Hay. Benguet, P. I. Mch 20, 1908" as the holotype.

Anopheles (*Kerteszia*) *homunculus* Komp, Ann. Ent. Soc. Amer. **30:** 509. 1937.

The syntype series of this species consisted of three females and one male. The collection now has two females and one male labeled as cotypes, associated with three numbered larval skins on one slide and the terminalia of the male on another slide. We select as lectotype the male with the associated larval skin no. 3, collected by Komp at Restrepo, Colombia, September 9, 1935.

Culex hyemalis Fitch, Amer. Journ. Agr. and Sci. **5:** 281. 1847.

The original description gives no indication of any type material, stating merely that the species is "met with in the last days of autumn and again for a short time in the first days of spring" and "is a somewhat rare insect." The collection contains a single female bearing the labels "6850 / Type No. ——— U.S.N.M. / Fitch Collection / Anopheles Meigen hyemalis Fitch New York." Not knowing whether any other Fitch specimens of this species are in existence, we select this specimen as lectotype.

Myzomyia rossi var. *indefinita* Ludlow, Can. Ent. **36:** 299. 1904.

This variety was described from an indefinite number of specimens from a variety of localities in the Philippines, some of them not named. The collection contains the following syntypes, or presumable syntypes: (1) Four females, each bearing the red label "Type No. 27779 U.S.N.M." (one of these specimens bears the label in Ludlow's hand "Myzomyia indefinita Ludl. P. I. Type C.S.L."); (2) two females labeled only "M. indefinita Ludlow Cotype"; and (3) nine specimens labeled only "Guimaras Isl. P. I. Dr. LeWald." These latter may not have been of the original Guimaras Island material, but they probably were. Most of the specimens are in very poor condition, particularly those of the first series, and except for the third series mentioned above, none bear any label for a specific locality in the Philippines. Since one of the best specimens, and one that agrees well with the original description and the current concept of the species, is one of the two of series (2) above, we select this one as lectotype.

Anopheles lewisi Ludlow, Psyche **27:** 14. 1920.

Aitken (1945, p. 308) designated lectotypes from the syntype series on which this name is based. This designation is somewhat obscure, since it appears that Aitken is referring to *lewisi* in making these selections but he uses two U. S. National Museum numbers. For the lectoholotype male he refers to U. S. National Museum no. 77812, which presumably refers to U.S.N.M. Type no. 27812, the number for the syntype series of *lewisi*; for the lectoallotype he says, "*A. Lewisi* (U. S. National Museum no. 77813)" which he may have intended to mean U.S.N.M. Type no. 27813, the type number for the two syntype females of *Anopheles selengensis* Ludlow. The collection contains a male and female of *lewisi*, labeled by Aitken as lectoholotype and lectoallotype respectively and a female of *selengensis* labeled lectoholotype, all collected at the same place and date. We accept the male lectotype for *lewisi*, and here designate as the lectotype of *selengensis* the female labeled by Aitken.

Stethomyia lewisi Shannon, Proc. Ent. Soc. Washington **33:** 154. 1931.

The male holotype, female allotype, and a female paratype were said to have been deposited in the U. S. National Museum collection. We have found no pinned specimens bearing type data, but there are two slides of fragments of male terminalia from the type locality, Rio Curupire, Bahia, Brazil. One of these slides has one complete set of terminalia and a portion of another, and the other has dissected claspettes. These slides are not labeled as types, and it would be impossible to tell which fragments belong to the holotype male, if any do. We can either assume that the type is lost or that the type is present in part but unlabeled.

Anopheles malefactor Dyar and Knab, Journ. New York Ent. Soc. **15:** 198. 1907.

The seven specimens on which this species was based are all in the collection and each bears the label "Type No. 10877 U.S.N.M." We select as

lectotype a female which also bears the labels "136.1 / Rio Chagres, Panama / Collected by August Busck / Anopheles malefactor D. & K. Type." There is a slide of the pupal skin and a portion of the abdomen of the larval skin. The fifth hind tarsomere is entirely white in this specimen, as given in the original description. Some of the other syntypes have a rather narrow dark ring on this tarsomere.

Anopheles neivai Howard, Dyar and Knab, Mosquitoes of North and Central America and the West Indies **4:** 966. 1917.

Although in the original description this species was said to have been found from Panama northward to southern Mexico, and localities are given in two places in Panama, two in Costa Rica, and one in Mexico, there are only three specimens in the collection under this name that can be considered to be of the original material. One of these, a female, bears the labels "344.1 / Type No. 20440 U.S.N.M. / neivai!" The number refers to Jennings' collection notes which state that the data for this number are "Fort San Felipe, Porto Bello Bay [Panama], June 2, 1908." The pupal skin and larval head capsule are mounted on a slide. This specimen we select as lectotype. A second female, from Panama, bears the label "Paratype No. 20440 U.S.N.M.," and a third one, from Estrella, Costa Rica, bears a determination label but no type label.

Anopheles occidentalis Dyar and Knab, Proc. Biol. Soc. Washington **19:** 159. 1906.

Most of the 118 original specimens of this species are in the collection, but only one, from Stanford University, California, May 26, 1903, bears a type label, and so we consider this to be the holotype. This specimen is in excellent condition. Aitken (1945, p. 285) has discussed the two species involved in the original series of this species.

Anopheles oiketorakras Osorno-Mesa, Caldasia **4:** 431–446, 1947.

This species was described from a male and a female designated as types, and other adults designated as paratypes. We select as lectotype the male "type" labeled "Bogotá, Colombia, S. A. Monserate, 2700–2840 m., III.13.46."

Myzomyia parangensis Ludlow, Psyche **21:** 129. 1914.

This species was described from more than one specimen, but the exact number was not stated. There are two females in the collection, each bearing the label "Type No. 27778 U.S.N.M." One is in excellent condition and bears the additional label "*Myzomyia parangensis* Ludl. Port of Parang, Mindanao, P. I., Oct. Nov. Types." The second is in poor condition and bears no additional label. Presumably the one label was intended for both. We select the first specimen as lectotype.

Anopheles philippinensis Ludlow, Journ. New York Ent. Soc. **10:** 129. 1902.

The number of specimens on which this species was based was not stated. Two females in the collection each bear the label "Type No. 27703 U.S.N.M." and one of them the label "Nyssorhynchus philippinensis Ludl. San Jose, Abra, P. I. Sept. 1, 1901. Type." Both of the specimens are in very poor condition, with hind legs missing. The one with palpi shows the terminal pale band on each palpus equal in length to the preapical dark band, and both specimens show a patch of pale scales on the sternopleuron, in both respects differing from the key characters used by Puri (1949). The specimen bearing Ludlow's original type label is in the worse condition, but the other is not much better. We refrain from selecting a lectotype because the specimens are in such poor condition that such selection would serve little purpose. The wing pattern differs slightly between the two specimens. If a lectotype is to be selected it should be only after a very thorough study of the species or species complex over its whole range.

Anopheles pseudobarbirostris Ludlow, Journ. New York Ent. Soc. **10:** 129. 1902.

The number of specimens on which this species was based was not stated. Two females in the collection each bears the label "Type No. 27782 U.S.N.M." and one of them the label "*Myzorhynchus pseudobarbirostris* Ludl. Type, Hagonoy, Bulacan, P. I. Oct. 2, 1901. Kellogg. Type." We designate this latter specimen as lectotype of the species.

Anopheles selengensis Ludlow, Psyche **27:** 77. 1920.

See remarks under *Anopheles lewisi* Ludlow.

Anopheles (*Nyssorhynchus*) *strodei* Root, Amer. Journ. Hyg. **6:** 711, 1926.

A male and a female of this species from the type locality are in the collection. We select as lectotype the male bearing a square of red paper and the labels "Agua Limpa, Braz. Mar. 27, 1925. No. 64 / Anopheles strodei Root types." The female bears the same data.

Myzomyia thorntonii Ludlow, Can. Ent. **36:** 69. 1904.

The collection contains three females of this species marked as types. Two of these each bear the label "Type No. 27780 U.S.N.M." put on by Dyar and one of these bears the additional label, in Ludlow's hand, "Myzomyia thorntonii Ludl. Cottabatto, Mindanao, P. I. June. Type C.S.L." The second specimen bears no data label, but Dyar entered both in the type book as being from the same locality. The third specimens bears an unnumbered type label and the label "M. Thorntoni Ludlow cotype" with no further data. Since Ludlow mentioned only two specimens, from two different localities, it is evident that some mislabeling has occurred. None of these specimens are in very good condition but they appear to be conspecific. We select as lectotype the specimen bearing the numbered type label and the collection data.

Anopheles vestitipennis Dyar and Knab, Proc. Biol. Soc. Washington **19:** 136. 1906.

The lectotype female designated by Stone in Russell, Rozeboom, and Stone (1943, p. 34) is in the collection.

The following taxa are based either on unique specimens or on clearly designated holotypes:

Anopheles (*Stethomyia*) *acanthotorynus* Komp, 1937
Anopheles (*Nyssorhynchus*) *anomalophyllus* Komp, 1936
Anopheles (*Kerteszia*) *anoplus* Komp, 1937
Anopheles lindesayi var. *benguetensis* King, 1931
Anopheles crucians var. *bradleyi* King, 1939
Anopheles (*Myzomyia*) *clowi* Rozeboom and Knight, 1946
Anopheles (*Myzomyia*) *cristatus* King and Baisas, 1936
Anopheles (*Nyssorhynchus*) *emilianus* Komp, 1941
Anopheles (*A.*) *fluminensis* Root, 1927
Anopheles crucians var. *georgianus* King, 1939
Anopheles (*Nyssorhynchus*) *goeldii* Rozeboom and Gabaldon, 1941
Anopheles gorgasi Dyar and Knab, 1907
Anopheles (*Nyssorhynchus*) *guarani* Shannon, 1928
Anopheles koliensis Owen, 1945
Anopheles nimbus var. *kompi* Edwards, 1930
Anopheles vagus var. *limosus* King, 1932
Chagasia lineata Ludlow, 1908
Anopheles litoralis King, 1932
Anopheles (*Myzomyia*) *lungae* Belkin and Schlosser, 1944
Anopheles (*Myzomyia*) *nataliae* Belkin, 1945
Anopheles (*Stethomyia*) *niveopalpis* Ludlow, 1919
Stethomyia pallida Ludlow, 1905
Anopheles perplexens Ludlow, 1907
Anopheles punctimacula Dyar and Knab, 1906
Anopheles (*Myzomyia*) *leucosphyrus* var. *riparis* King and Baisas, 1936
Anopheles (*A.*) *samarensis* Rozeboom, 1951
Anopheles (*A.*) *saperoi* Bohart and Ingram, 1946
Anopheles (*Nyssorhynchus*) *sawyeri* Causey, Deane, Deane, and Sampaio, 1943
Anopheles (*A.*) *shannoni* Davis, 1931
Anopheles (*Myzomyia*) *solomonis* Belkin, Knight, and Rozeboom, 1945
Anopheles strigimacula Dyar and Knab, 1906

Genus **Chagasia** Cruz

Chagasia rozeboomi Causey, Deane and Deane, Amer. Journ. Hyg. **39:** 3. 1944; Journ. Nat. Malaria Soc. **4:** 341–350. 1945.

The first description of this species was of the egg only and there is probably no type specimen in existence. In 1945 the authors described the adults, larva, and pupa, and state that "Type specimens are deposited in the National Museum in Washington, D. C. U.S.A." A female in the collection bears the labels "Type specimen collected in Crato, Ceara, Brazil / Type No. 58039 U.S.N.M. / Chagasia rozeboomi Causey Deane and Deane 1944." Since the species was originally described from the egg alone, however, we must consider this specimen as a pseudotype.

The following species are based on unique holotype specimens:

Anopheles (*Chagasia*) *bathanus* Dyar, 1928
Chagasia bonneae Root, 1927

LITERATURE CITED

AITKEN, T. H. G. *Studies on the anopheline complex of western America.* Univ. California Publ. Ent. **7:** 273–364. 1945.

PURI, I. M. Anopheles *of the Oriental Region. In* Boyd, Malariology **1:** 483–505. 1949.

ROSS, E. S., and ROBERTS, H. R. *Mosquito Atlas Part I:* 1–44. American Entomological Society, 1943.

RUSSELL, P. F., ROZEBOOM, L. E., and STONE, A. *Keys to the anopheline mosquitoes of the world:* 1–152. American Entomological Society, 1943.

VARGAS, L., and MATHESON, R. *Estado actual del* Anopheles earlei *Vargas (1943) y* Anopheles occidentalis *Dyar & Knab (1906) con claves para larvas, pupas y adultos del llamado complejo* maculipennis *de Norteamerica.* Rev. Inst. Salub. y Enferm. Trop. **9:** 27–33. 1948.

ZOOLOGY.—*Some polychaete worms of the families Hesionidae, Syllidae, and Nereidae from the east coast of North America, West Indies, and Gulf of Mexico.*[1]

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In connection with a study in progress on the polychaetes of the New England region, a species of Hesionidae is herein revised, resulting in a new genus and new combination; a new species of each of the Syllidae and Nereidae are described. From the West Indies and Gulf of Mexico region, a new species of Nereidae is described and supplementary descriptions are given for two other nereid species. The major part of the work was done at the United States National Museum, where the types are deposited.

Family HESIONIDAE

Parahesione, n. gen.

Diagnosis.—Prostomium with two lateral antennae, two smooth, unjointed palps, two pairs of eyes. Tentacular segments 3, somewhat fused; tentacular cirri 6 pairs (3 pairs on each side). Parapodia distinctly biramous; notopodia forming distinct lobes below the cirrophores of the dorsal cirri, with numerous capillary notosetae; neuropodia with numerous compound setae with blades long and slender. Anal cirri two, long. Proboscis with numerous fine papillae around the opening, without jaws.

Type.—*Podarke luteola* Webster, 1880 (= *Hesione agilis* Webster and Benedict, 1884).

Parahesione resembles *Syllidea* Quatrefages, *Micropodarke* Okuda, and *Nereimyra* Blainville (= *Castalia* Savigny) in the absence of a median antenna, the presence of 2 palps and 6 pairs of tentacular cirri. It differs from them in that the notopodia are well developed and distinct from the cirrophores of the dorsal cirri, with a distinct bundle of numerous notosetae; the palps are smooth, not biarticulate; also the shape of the neuropodia and probosces differ markedly.

Parahesione luteola (Webster, 1880), n. comb.
Fig. 1, *a–c*

Podarke luteola Webster, 1880, pp. 107–108 (figures referred to not published); 1886, pp. 135–136, pl. 5, figs. 19–20 (repeat of Webster, 1880, plus figures).

Hesione agilis Webster and Benedict, 1884, pp. 707–709, pl. 1, figs. 9–11.

The revision of the species is based on the following: (1) The description of *Podarke luteola* Webster, 1880, 1886, based on a single specimen (11 mm long, 45 segments) found on an oystershell in Great Egg Harbor, N. J.; the type specimen is not available; (2) the description and type specimens of *Hesione agilis* Webster and Benedict, 1884 (U.S.N.M. no. 430), found in sandy mud near the high water mark in Wellfleet, Mass.; the types include several small specimens (up to 2.5 mm long, 18 setigers); (3) several specimens collected at Wellfleet Harbor, Mass., on the sandy flats, living commensally in the burrows of *Upogebia affinis* (Say); they move rapidly and easily escape notice; they were up to 15 mm long, 4 mm wide including setae, 37 setigers.

Description.—Length up to 15 mm, width including setae up to 4 mm, segments 18–45. Body widest in the middle, tapering gradually anteriorly and posteriorly, flattened dorsoventrally. Prostomium (Fig. 1, *a*) much wider than long, with 2 pairs dark red eyes, crescentric, closely approximated on each side; two pairs of similar anterior appendages, both pairs delicate, subulate, with very short basal ceratophores; of these anterior appendages, the lateral antennae are slightly more dorsal in position; the palps are smooth, not biarticulate as in many hesionids; a median antenna is lacking (for *Podarke luteola*, Webster indicated it was lost). Three tentacular segments somewhat fused dorsally, usually only one distinct; the 3 pairs of tentacular cirri on each side with short cylindrical basal cirrophores emerging from a common base, lateral to and somewhat fused with the prostomium; styles variable in length, the upper ones longer than the lower ones (some may reach segment 10), readily lost and renewed.

Parapodia, dorsal cirri, and setae all very long (Fig. 1, *c*). Parapodia distinctly biramous; notopodium a stout papilla below the base of the dorsal cirrus; notosetae numerous, forming a close-set bundle, long (longer than the neurosetae), slender, capillary, transversely striated.

[1] This study was aided by a grant from the National Science Foundation (NSF-G2012).

Neuropodia stout, elongated, terminating above in a conical acicular process, diagonally truncate below; neurosetae form a fan-shaped group, compound, stem very long with transverse markings, appendages short and long, entire. Dorsal cirri with short cylindrical basal cirrophores; styles very long (longer than the setae), delicate, tapering uniformly, articulate. Ventral cirri delicate, conical, tapering to slender tips, extending slightly beyond the tips of the neuropodial lobes. Anal cirri long, similar to the dorsal cirri (Fig. 1, *b*). Proboscis eversible, with larger basal portion and narrower distal portion, with numerous fine papillae around the opening, without jaws. Color: Colorless (small specimens) to reddish yellow, parapodia green and yellow, cirri white; greenish (preserved).

Family SYLLIDAE

Genus **Brania** Quatrefages, 1866

Brania wellfleetensis, n. sp.

Fig. 2, *a–c*

The species is based on a single specimen collected at low water, Wellfleet Harbor, on the Cape Cod Bay side, Massachusetts, on sandy bottom among tubes of *Diopatra cuprea* (Bosc), August 25, 1953 (U.S.N.M. no. 27783); another specimen was collected at Chappaquoit, Buzzards Bay, Mass., in muddy sand (U.S.N.M. no. 27784).

Description.—Length up to 7 mm, width up to 0.4 mm, segments 38–39. Body tiny, slender, threadlike, cylindrical, widest in the middle, tapering slightly anteriorly and posteriorly, colorless. Prostomium oval, wider than long, with 2 pairs of eyes, anterior pair slightly larger and more lateral, with little extra pigment lateral to the posterior pair of eyes; antennae subulate, wider basally, tapering to more slender tips; median antenna attached posteriorly on prostomium between posterior pair of eyes, about double the length of the prostomium; lateral antennae attached anteriorly on prostomium, anterior to the anterior pair of eyes, extending about as far distally as the median antenna; palps large, prominent, fused on basal third, free distally; the palps may be elongated (Fig. 2, *b*, sketched from life) or somewhat contracted (Fig. 2, *a*, preserved). Tentacular segment more or less distinct, with 2 pairs of tentacular cirri, subequal, similar in shape and length to the median antenna. Uniramous parapodia with setae all compound, except in the last 6 or so posterior segments where there is an upper and lower simple seta (looks like a compound seta that has lost its appendage and become somewhat worn); setae compound falcigerous, with blades short, finely spinous, with tips hooked and entire (Fig. 2, *c*). First pair dorsal cirri equal in length to tentacular cirri; dorsal cirri lacking on setiger 2; rest of dorsal cirri slightly longer than setal tips. Ventral cirri extend to about the tips of the parapodial lobes. Anal cirri 2, about as long as last 3 segments. Pharynx long, occupying setigers 1–4, may be somewhat coiled when body is contracted; proventriculus occupying setigers 5 to 8.

Remarks.—*Brania wellfleetensis* differs from *Brania clavata* (Claparède), which includes *Grubea websteri* Verrill and is known from the New England region, in the following:

	B. clavata	*B. wellfleetensis*
Parapodial setae	Two kinds: single upper simple one; compound setae with blades shorter to longer, with tips finely bidentate.	Setae all compound (except for some simple setae in last 6 or so posterior segments), with tips of blades entire.
Prostomium	With a pair of small ocular spots near the lateral antennae, in addition to the 4 larger eyes.	Without ocular spots.
Dorsal cirri on setiger 2	Present.	Absent.

Distribution.—Massachusetts (Wellfleet Harbor, Chappaquoit). In low water.

Family NEREIDAE

Nereis (Nereis) grayi, n. sp.

Fig. 3, *a–g*

The species is based on two specimens collected at Hadley Harbor, Uncatena Island in the Woods Hole area, Massachusetts, August 1952 (U.S.N.M. no. 27781, 27782). They were collected by Milton Gray, after whom the species is named. They were found in the thick muddy tubes of the large maldanid, *Maldanopsis elongata* (Verrill). Whether or not they lived commensally with the maldanid or occupied the tube secondarily is difficult to say. An examination of numerous tubes later failed to reveal any of the nereids.

Description.—Length up to 60 mm or more, width up to 5 mm, segments up to 150 or more. Body long, slender, tapering very gradually posteriorly, somewhat flattened dorsoventrally,

colorless. Prostomium (Fig. 3, *a*) typical nereid shape, being widest on posterior third, tapering gradually anteriorly to a truncate tip; frontal antennae subulate, at the corners of the truncate tip; palps with basal part large and bulbous, with retractile tip; 4 eyes rather small, subequal, on posterior third of prostomium. Tentacular segment about same length as the following segments; tentacular cirri slender, tapering, the posterior dorsal pair longest, extending to about setiger 8. Anal segment with a pair of short anal cirri.

Parapodia (Fig. 3, *d*, *e*) biramous, except for the first two uniramous pairs, similar throughout the length of the body; they are long, making up about two-thirds the width of the body. Notopodium with 2 subequal, elongated, conical, pointed ligules; neuropodium with bluntly conical setigerous lobe, with a slightly shorter, conical, pointed lower ligule. Both dorsal and ventral cirri are shorter than the ligules. Notosetae of anterior region homogomph spinigers, rather few in number (about 8 in each notopodium), with rather short blades; beginning on about setiger 27, notopodia with few (1–2), homogomph falcigers with oval blades (Fig. 3, *g*). Upper group of neurosetae homogomph spinigers with long slender blades and few heterogomph falcigers (may be lacking on some parapodia); lower group of neurosetae heterogomph spinigers with rather short blades and heterogomph falcigers with rather long blades (Fig. 3, *f*). Acicula dark amber-colored. Proboscis (Fig. 3, *a–c*) with a pair of brown amber-colored jaws, each with about 12 teeth, with paragnaths few in number and small in size; on the maxillary ring: area II with 2 to 3 very small ones; area IV with triangular group of 10 to 13 slightly larger ones; on the oral ring, area VI with 3 to 4 small ones; paragnaths lacking on the other areas.

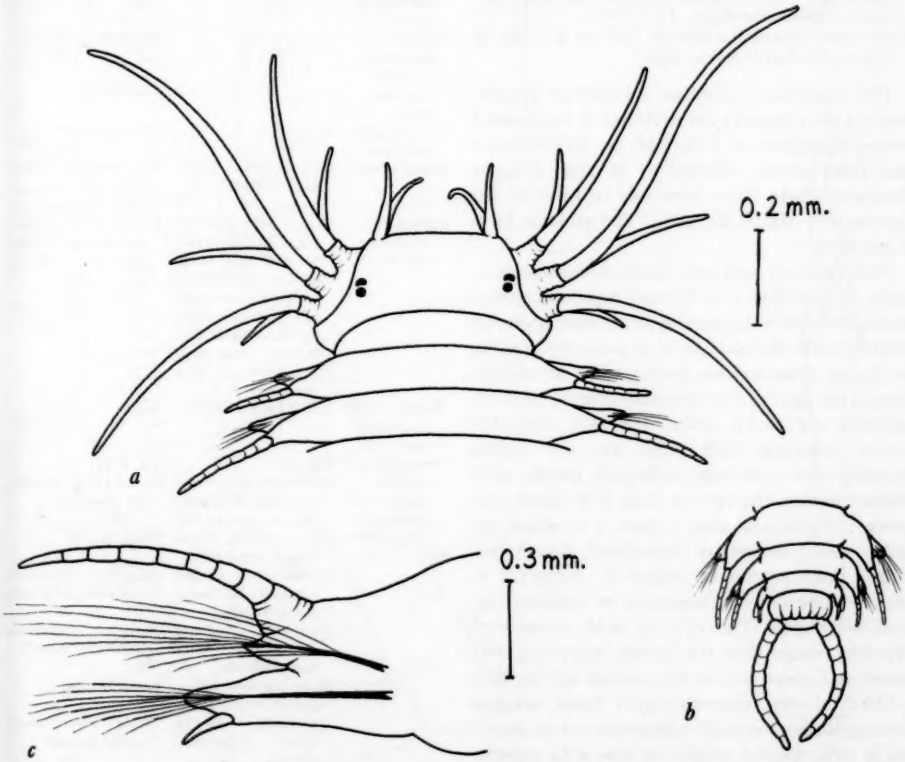

FIG. 1.—*Parahesione luteola*, n. comb.: *a*, Dorsal view anterior end; *b*, dorsal view posterior end; *c*, parapodium.

Remarks.—*Nereis grayi* resembles *Nereis* (*Eunereis*) *longissima* Johnston rather closely, including the parapodia and the few paragnaths on the proboscis; they differ in the following:

	N. longissima	*N. grayi*
Paragnaths	Confined to small group on area VI of oral ring, without paragnaths on maxillary ring.	Small group on areas II and IV of maxillary ring; small group on area VI of oral ring.
Tentacular cirri	Shorter, longest reach about setiger 3.	Longer, longest reach about setiger 8.
Notopodial homogomph falcigers	Begin on about setiger 65.	Begin on about setiger 27.

Distribution.—Massachusetts (Woods Hole region). In low water.

Nereis egregicirrata Treadwell, 1924

Fig. 4, *a*; 5, *a–d*

Nereis (*Leptonereis*) *egregicirrata* Treadwell, 1924, pp. 13–14, fig. 24 (part; English Harbor, Antigua, submarine light, July 1918).

Nereis egregicirrata Treadwell, 1939, p. 233, fig. 56 (Santa Barbara, Porto Rico).

The following description is based on 5 specimens in the original type material (2 male and 3 female heteronereids, U.S.N.M. no. 20324) and a male heteronereid collected by M. Jean Allen at Parguera, Porto Rico, from reef in front of the Laboratory, March 23, 1955. The atokous form is unknown.

Description of male and female heteronereids.—Body divided into two distinct regions: anterior unmodified, with the usual type of setae; posterior modified with the usual type of setae replaced by swimming setae and the development of lamellae instead of ligules. Prostomium (Fig. 4, *a*) with anterior part bent down ventrally, thus the frontal antennae and palps are not visible dorsally; four eyes large, subequal, purple, with distinct lenses, the two on each side closely appressed. Tentacular cirri 4 pairs, 3 of which are rather short, somewhat articulated, fourth pair longer, may extend to setiger 5, distinctly to slightly articulated. Parapodia of anterior unmodified region (Fig. 5, *a*, *c*) with dorsal cirri subulate, longer than the ligules; notopodia with upper and lower conical to rounded ligules, with a third, shorter (supraacicular) ligule between them, with homogomph spinigerous setae; neuropodia with conical setigerous lobe with anterior and posterior lips, with lower conical ligule; upper group of neurosetae homogomph spinigers and heterogomph falcigers; lower group of neurosetae heterogomph spinigers and falcigers; heterogomph falcigers with short blades, similar to Fig. 6, *c*; ventral cirri subulate, about same length or slightly shorter than the neuropodial ligule; acicula dark amber-colored. Proboscis with amber-colored jaws each with about 12 teeth; with conical paragnaths on both maxillary and oral rings (exact arrangement?). Color (in alcohol): With faint transverse brownish bands dorsally and with darker glandular areas dorsally at bases of parapodia. The male and female heteronereids differ in the following:

	Male heteronereid	*Female heteronereid*
Length	Up to 13 mm.	Up to 14 mm
Width	Up to 1.5 mm in anterior region; up to 2.5 mm in posterior region	Up to 1 mm in anterior region; up to 2 mm in posterior region
Number of setigers in anterior unmodified region	18	26
Number of setigers in posterior modified region	About 67	About 90
Total number of setigers	About 85	About 116
Posterior end	Anal segment papillated (anal cirri broken off)	Pair of long articulated anal cirri; anal segment papillated
Dorsal cirri of anterior region	First 7 pairs modified (fig. 4, a): first 5 and seventh pairs elongate, cylindrical, with asymmetrical tips; sixth pair enormously elongate with bulbous base and long style (up to 4 mm long)	First 7 pairs modified, get gradually longer anterior to posterior
Ventral cirri of anterior region	First 5 pairs clubbed	Same
Parapodia of modified region, with with swimming setae	Fig. 5, *b*.	Fig. 5, *d*.
	Dorsal cirri with slight indication of annulations or crenulations	Dorsal cirri smooth, not crenulate
	Extra lamella above base of dorsal cirrus	Same, smaller
	Unequally bilobed supraacicular notopodial lamella	Single digitiform supraacicular lamella
	Unequally bilobed subacicular notopodial lamella	Single subacicular notopodial lamella
	Large postsetal neuropodial lamella	Same, smaller
	Unequally bilobed lower neuropodial lamella	Single lower neuropodial lamella
	Ventral cirri with bilobed lamella above and large lamella below	Ventral cirri with single lamella above and smaller lamella below

Remarks.—The types of *Nereis* (*Leptonereis*) *egregicirrata* Treadwell were collected by submarine light at English Harbor, Antigua, by the Barbados-Antigua Expedition from the University of Iowa. The nine specimens present in the type material are a mixture of male and female heteronereids of at least two species. Since the description is confusing, being based on more than one species, I have selected as lectotype for *N. egregicirrata* one of the two male heteronereids with the enormously elongated dorsal cirri on setiger 6, as figured by Treadwell (1924, fig. 24). The rest of the specimens were separated as follows:

Anterior notopodia with 3 ligules (Fig. 5, *a*, *c*):
Male heteronereids: With enormously elongated dorsal cirri on setiger 6 (Fig. 4, *a*; fig. 24 in Treadwell, 1924); dorsal cirri of modified region crenulate (Fig. 5, *b*); anterior unmodified region with 18 setigers.—Lectotype and paratype of *N. egregicirrata*, 2 specimens.

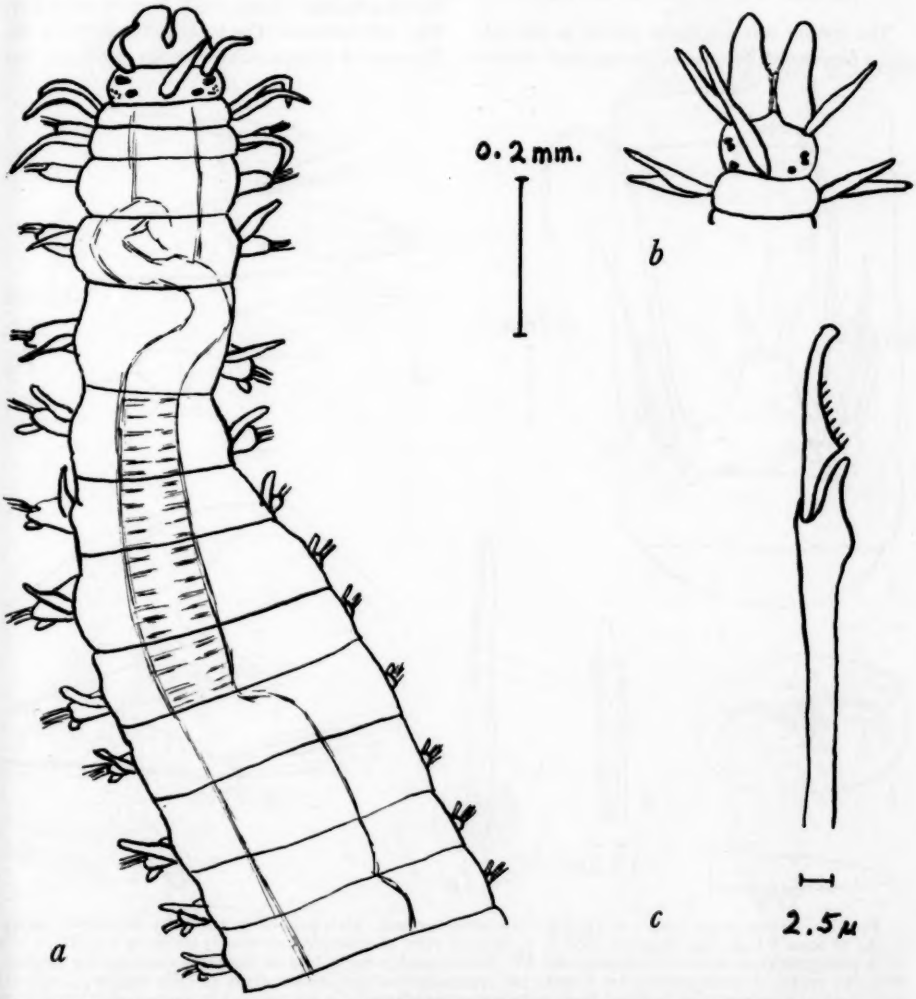

FIG. 2.—*Brania wellfleetensis*, n.sp.: *a*, Dorsal view anterior end; *b*, dorsal view prostomium, sketched from life; *c*, compound falcigerous seta.

Female heteronereids: Dorsal cirri of modified region smooth, not crenulate (Fig. 5, *d*); anterior unmodified region with 26 setigers. —Paratypes of *N. egregicirrata*, 3 specimens.

Anterior notopodia with 2 ligules (Fig. 6, *a*):

Male heteronereids: Dorsal cirri of modified region crenulate (Fig. 6, *h*); anterior unmodified region with 14 setigers.—Paratypes of *N. allenae*, n. sp., 3 specimens.

Female heteronereid: Dorsal cirri of modified region smooth, not crenulate (Fig. 6, *g*); anterior unmodified region with 26 setigers, filled with large yolky eggs (Fig. 4, *d*).—Paratype of *N. allenae*, n. sp., 1 specimen.

The species was originally placed in the subgenus *Leptonereis* because of the supposed absence of paragnaths. Treadwell, 1939, indicated that paragnaths were present and referred it to *Nereis*. The males and females of the two species are superficially similar and agree in the following: They are all small, less than 15 mm long; they are mostly faintly transversely banded with darker glandular areas at the dorsal bases of some of the parapodia; the anterior part of the prostomium is bent ventrally, so that the palps and frontal antennae are not visible dorsally; the 4 eyes are large, purple, subequal, with prominent lenses.

Nereis egregicirrata suggests a resemblance to *Nereis articulata* Ehlers, 1887, from off Sand Key, Fla., 120 fathoms. The type of the latter in the Museum of Comparative Zoology, Harvard, was

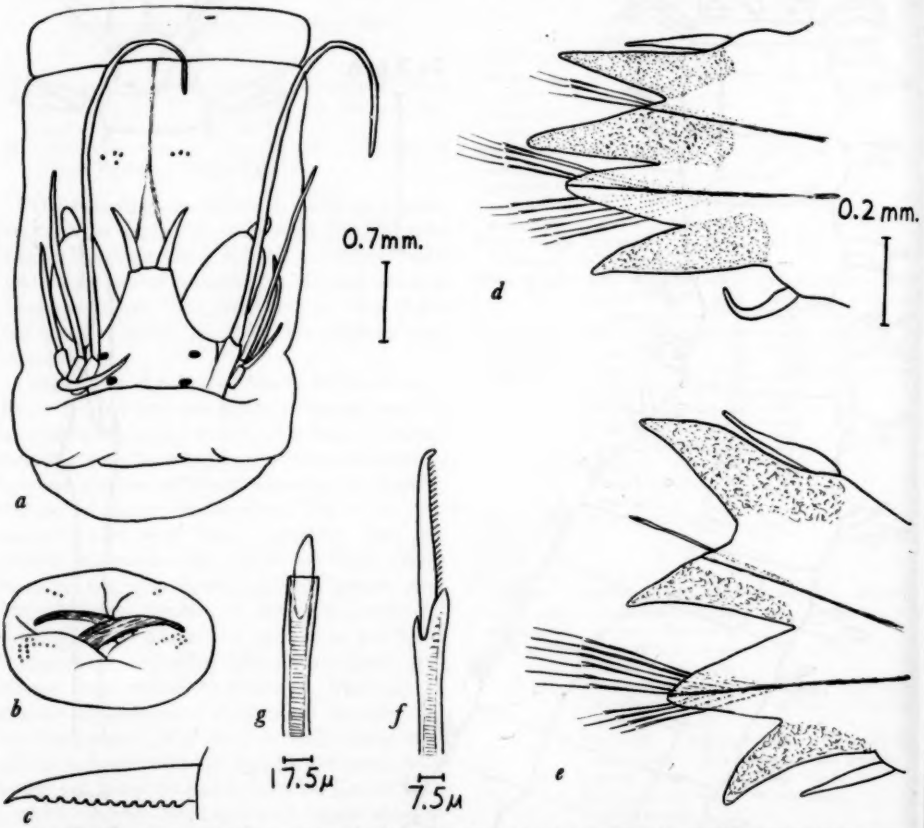

FIG. 3.—*Nereis grayi* n.sp.: *a*, Dorsal view anterior end, with proboscis partially extended; paragnaths of area VI on oral ring are shown; *b*, frontal view of extended proboscis showing maxillary ring with paragnaths on areas II (upper) and IV (lower) and jaws; *c*, one of the jaws showing the arrangement of teeth; *d*, parapodium from anterior region of body; *e*, same, from middle region; *f*, a lower neuropodial heterogomph falciger from anterior parapodium; *g*, a notopodial homogomph falciger from middle parapodium.

examined for comparison; it is a single small atokous form in very poor condition—it is brittle, brown, with pharynx and most of the setae missing. The species agree in that the tentacular cirri are articulated, the parapodia seem similar; also they have glands at the bases of the parapodia. A similar type of elongated dorsal cirri for the male heteronereid is reported for *Nereis abnormis* Horst, 1924, p. 163, from the Netherlands East Indies; in this case, it is the dorsal cirri of the seventh setiger that is enlarged instead of the sixth as in *N. egregicirrata*.

Distribution.—West Indies: Antigua, Puerto Rico; in surface waters (March, July).

Nereis allenae, n. sp.

Figs. 4, *b–f*; 6, *a–h*

The description is based on the following: Type (U.S.N.M. no. 27778): A single female heteronereid massed with unusually large eggs

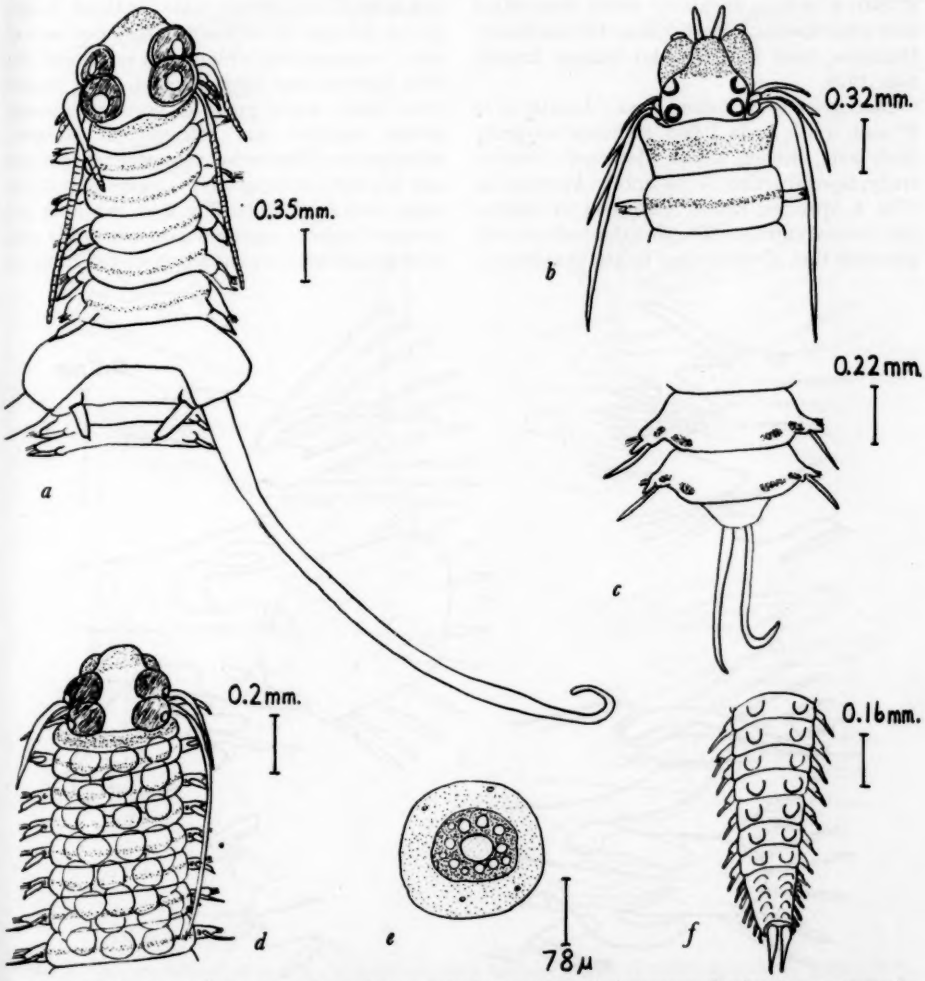

FIG. 4.—*Nereis egregicirrata: a*, Dorsal view anterior end of male heteronereid showing enormously elongated dorsal cirri on setiger 6. *Nereis allenae*, n.sp.: *b*, Dorsal view anterior end of atokous form; *c*, dorsal view posterior end of same; *d*, dorsal view anterior end of female heteronereid; *e*, one of large yolky eggs of same; *f*, dorsal view posterior end of male heteronereid.

from reef between the Laboratory and Caballo Blanco Island, Parguera, Porto Rico, evening, 15 September 1955, collected by M. Jean Allen, after whom the species is named; it is unusual in that the eggs were laid in short alga-like strings; paratypes (U.S.N.M. no. 27779): a single female heteronereid (massed with large eggs) and 3 male heteronereids removed from the type material of *Nereis egregicirrata* Treadwell (see above), collected at submarine light, English Harbor, Antigua, July 1918; paratypes (U.S.N.M. no. 27780): 3 atokous specimens which were mixed with other species, collected from Pelican Island, Barbados, from the Barbados-Antigua Expedition, 1918.

Description of the atokous form.—Length up to 27 mm, width up to + mm, segments about 80. Body long, slender, slightly flattened dorsoventrally, tapered gradually posteriorly. Prostomium (Fig. 4, *b*) widest basally, narrowed on anterior half; frontal antennae slender, palps bulbous with retractile tips, of about same length as antennae; 4 eyes on posterior half of prostomium, violet, rather large, subequal. Tentacular segment of about same length as following segments; tentacular cirri short to longer, the longest reach setiger 4. Posterior end (Fig. 4, *c*) with bulbous anal segment, with pair of long anal cirri. Parapodia (Fig. 6, *a*, *b*) similar throughout the length of the body. Dorsal cirri much longer than the ligules; notopodium with 2 rounded to conical ligules, with small acicular lobe on upper side of lower ligule (no distinct middle ligule), with homogomph spinigerous setae (without homogomph falcigers in middle and posterior part of body); neuropodium with conical setigerous lobe with anterior and posterior lips, with conical lower ligule; upper group of neurosetae homogomph spinigers and heterogomph falcigers; lower group of neurosetae heterogomph spinigers and falcigers; heterogomph falcigers of anterior region with short blades (Fig. 6, *c*); in middle and posterior regions, upper group of neurosetae with homogomph spinigers and few (1–3) heterogomph

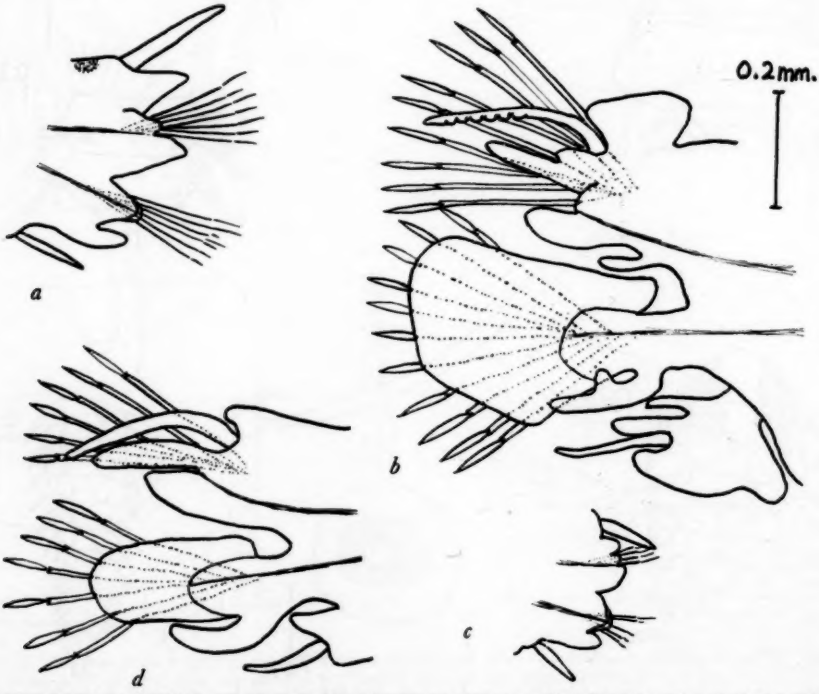

FIG. 5.—*Nereis egregicirrata: a*, Parapodium from anterior unmodified region of male heteronereid; *b*, parapodium from posterior modified region of same; *c*, parapodium from anterior unmodified region of female heteronereid; *d*, parapodium from posterior modified region of same. (All parapodia drawn to same scale.)

falcigers that are stouter than the others (Fig. 6, *d*); lower group of falcigers more slender with short blades (Fig. 6, *e*); acicula dark amber-colored. Proboscis with dark amber-colored jaws, with conical amber-colored paragnaths on both maxillary and oral rings (exact arrangement?). Color (in alcohol): With brownish pigment on anterior part of prostomium including palps, with a wide band on the tentacular segment and narrow transverse bands both dorsally and

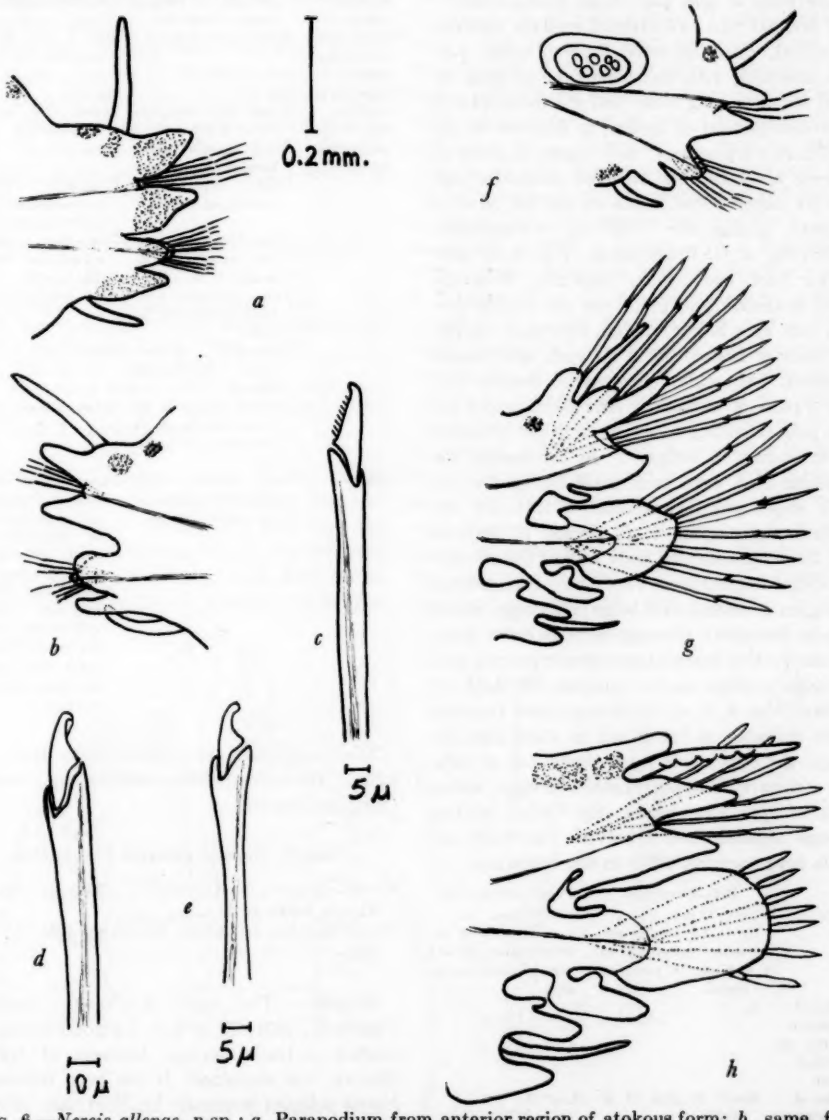

FIG. 6.—*Nereis allenae*, n.sp.: *a*, Parapodium from anterior region of atokous form; *b*, same, from middle region of body; *c*, heterogomph falcigerous seta from anterior parapodium of atokous form; *d*, heterogomph falcigerous seta from upper group of neurosetae from middle parapodium of atokous form; *e*, same, from lower group of neurosetae; *f*, parapodium from anterior part of body of female heteronereid; *g*, same, from posterior modified region; *h*, parapodium from modified region of male heteronereid. (All parapodia drawn to same scale.)

ventrally on most of the segments; also brownish glandular areas laterally within the body—at the bases of the parapodia dorsally and ventrally, at the bases of the dorsal and ventral cirri, and in the ligules (Fig. 4, *b*, *c*).

Description of male and female heteronereids.—Body divided into two distinct regions: anterior unmodified, with the usual type of setae; posterior modified, with the usual type of setae replaced by swimming setae and the development of lamellae instead of ligules; in addition in the male, there is a posterior "tail" region of about 12 segments which lack the modified parapodia; also there are paired dorsal knobs on the last 19 or so segments, giving the "tail" a characteristic aspect (Fig. 4, *f*). Prostomium (Fig. 4, *d*) with anterior part bent down ventrally, thus the frontal antennae and palps are not visible dorsally; four eyes large, bulging, subequal, purple, with distinct lenses, the 2 on each side closely appressed. Tentacular segment of female with lower 2 pairs of tentacular cirri short, upper anterior pair extending to setiger 2, upper posterior pair extending to setiger 7; in the males, the tentacular cirri were broken off except for one rather short pair. Parapodia of anterior unmodified region (Fig. 6, *f*) similar to atokous form. In the female, the body wall of the anterior unmodified segments is very thin, transparent; this region is massed with large yolky eggs (about 160 μ in diameter); the eggs have an outer finely granular portion and an inner denser portion with the large nucleus and a number of large oil globules (Fig. 4, *d*, *e*); these eggs were reported by the collector as being laid in short alga-like strings; the eggs made up a single row of cells, some strings with approximately 30 eggs; within about an hour after laying, the "jelly" holding the eggs together had dissolved. The male and female heteronereids differ in the following:

	Male heteronereid	*Female heteronereid*
Length	Up to 12 mm.	Up to 14 mm
Width	Up to 1.5 mm in anterior region; up to 2.5 mm in posterior region	Up to 1.5 mm in anterior region; up to 2 mm in posterior region
Number of setigers in anterior unmodified region	14	26
Number of setigers in posterior modified region	About 46 plus 12 in "tail"	About 55
Total number of setigers	About 72	About 81
Posterior end	Pair of dorsal papillae (ventral anal cirri missing); with a pair of dorsal knobs on the last 19 or so segments (Fig. 4, *f*)	Bulbous anal segment (anal cirri missing)
Dorsal cirri of anterior region	First 7 pairs elongated, clubbed, become longer posteriorly	First 5 pairs slightly modified, clubbed
Ventral cirri of anterior region	First 4 pairs clubbed	First 5 pairs slightly modified, clubbed
Parapodia of modified region with swimming setae	Fig. 6, *h*	Fig. 6, *g*
	Dorsal cirri crenulate on lower margin	Dorsal cirri smooth, not crenulate
	Extra lamella above base of dorsal cirrus	Same
	Single supraacicular notopodial lamella	Unequally bilobed supraacicular notopodial lamella
	Single large subacicular notopodial lamella	Unequally bilobed subacicular notopodial lamella
	Large rounded postsetal neuropodial lamella	Same, smaller
	Unequally bilobed lower neuropodial lamella	Same
	Ventral cirri with bilobed lamella above and large lamella below	Same, smaller
Color	Not banded; dark glands at bases of parapodia dorsally	Pigmented on anterior part of prostomium and palps, wide band on tentacular segment, with narrow transverse bands on rest of segments dorsally and ventrally, with darker spots at the bases of the parapodia and bases of the dorsal and ventral cirri.

Distribution.—West Indies: Porto Rico, Antigua, Barbados; heteronereids at surface (July, September).

Nereis (Nereis) pelagica Linné, 1758

Nereis largoensis Treadwell, 1931, p. 3.—not Behre, 1950, p. 12.
Nereis pelagica largoensis Hartman, 1956, pp. 255, 280.

Remarks.—The type of *Nereis largoensis* Treadwell, 1931, from Key Largo, Florida, deposited in the American Museum of Natural History, was examined. It has been referred to *Nereis pelagica largoensis* by Hartman, 1956. In comparing it with specimens of the more northern *N. pelagica*, it seems to be identical; the paragnath arrangement falls within the variation found in *N. pelagica*; the posterior notopodial

lobes are no more enlarged than is found in the more northern forms. The record of *N. largoensis* from Grand Isle, La., by Behre, 1950, was based on specimens deposited in the United States National Museum and identified by Treadwell; on examination, they proved to be *occidentalis* and not *largoensis*.

Distribution.—Widely distributed in the Arctic. Also Iceland, Norway to Mediterranean; Hudson Bay to Long Island Sound, Florida (Key Largo); Bering Sea to Panamá; north Japan Sea to Japan; South Atlantic (Tristan da Cunha, Kerguelen, Magellan Straits). In low water to 609 fathoms.

Nereis (Nereis) occidentalis Hartman, 1945

Fig. 7, *a–d*; 8, *a–g*

Nereis pelagica occidentalis Hartman, 1945, p. 20, pl. 4, figs. 1–6; 1951, p. 46.—Behre, 1950, p. 12.
Neanthes oligohalina Rioja, 1946, p. 207, pl. 1, figs. 3–6; pl. 2, figs. 13–19.
Nereis largoensis Behre, 1950, p. 12.—Hartman, 1951, p. 45, pl. 13, fig. 5 (part; from Grand Isle, La.); not Treadwell, 1931.

Heteronereid epitokous forms of this species (including a single female and 7 males) were collected by Joseph P. Breuer and sent into the Museum for identification; they were collected in Laguna Madre, 25 miles north of Port Isabel, Tex., at night under light, April 15, 1956. The females have not been described previously and the males only partially. They are described herein and compared with the atokous form. The known distribution of the species is extended from collections in the United States National Museum.

Description of atokous form.—Length up to 50 mm, width up to 4 mm, segments about 80. Prostomium of the typical nereid form, with the 4 eyes rather large, subequal. Tentacular segment with 4 pairs of tentacular cirri, the longest reach setigers 3 to 8. Parapodia of anterior region (Fig. 8, *a*) with ligules short and rounded; the ligules become slightly more elongated and conical in the middle and posterior regions (Fig. 8, *b*, *c*). Notopodium with 2 ligules, with a very small supraacicular setigerous lobe between them (not a distinct third ligule); neuropodium with a rounded to conical setigerous lobe and a lower ligule. Dorsal cirri longer than the ligules, ventral cirri slightly shorter. Notosetae of anterior region consist of homogomph spinigers; in the middle and posterior regions, the notosetae become fewer in number, with few (1–2) homogomph falcigers in addition to the spinigers; homogomph falcigers with short blades, with recurved tip and spinous edge (spines may be worn; Fig. 7, *c*, *d*). Upper group of neurosetae homogomph spinigers and heterogomph falcigers; lower group of neurosetae heterogomph spinigers and falcigers; hetero-

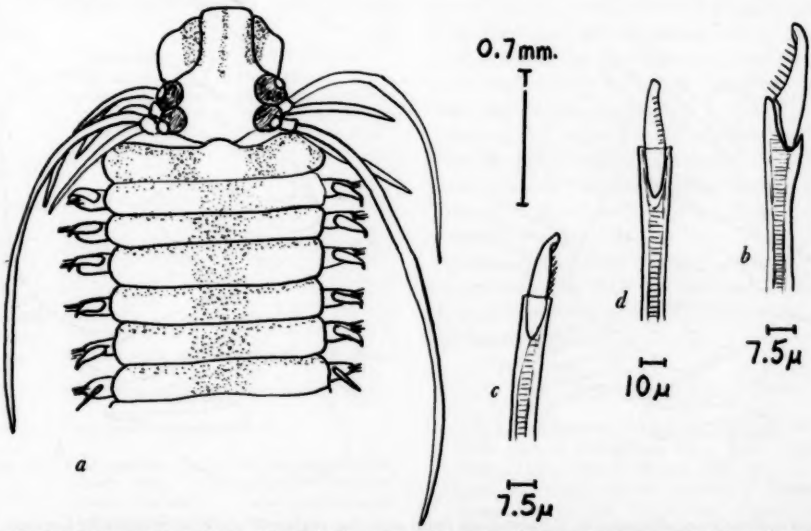

FIG. 7.—*Nereis occidentalis: a*, Dorsal view anterior end of female heteronereid; *b*, heterogomph falcigerous neuroseta from anterior region of atokous specimen; *c*, homogomph falcigerous notoseta from posterior region of atokous specimen; *d*, same, from slightly different angle.

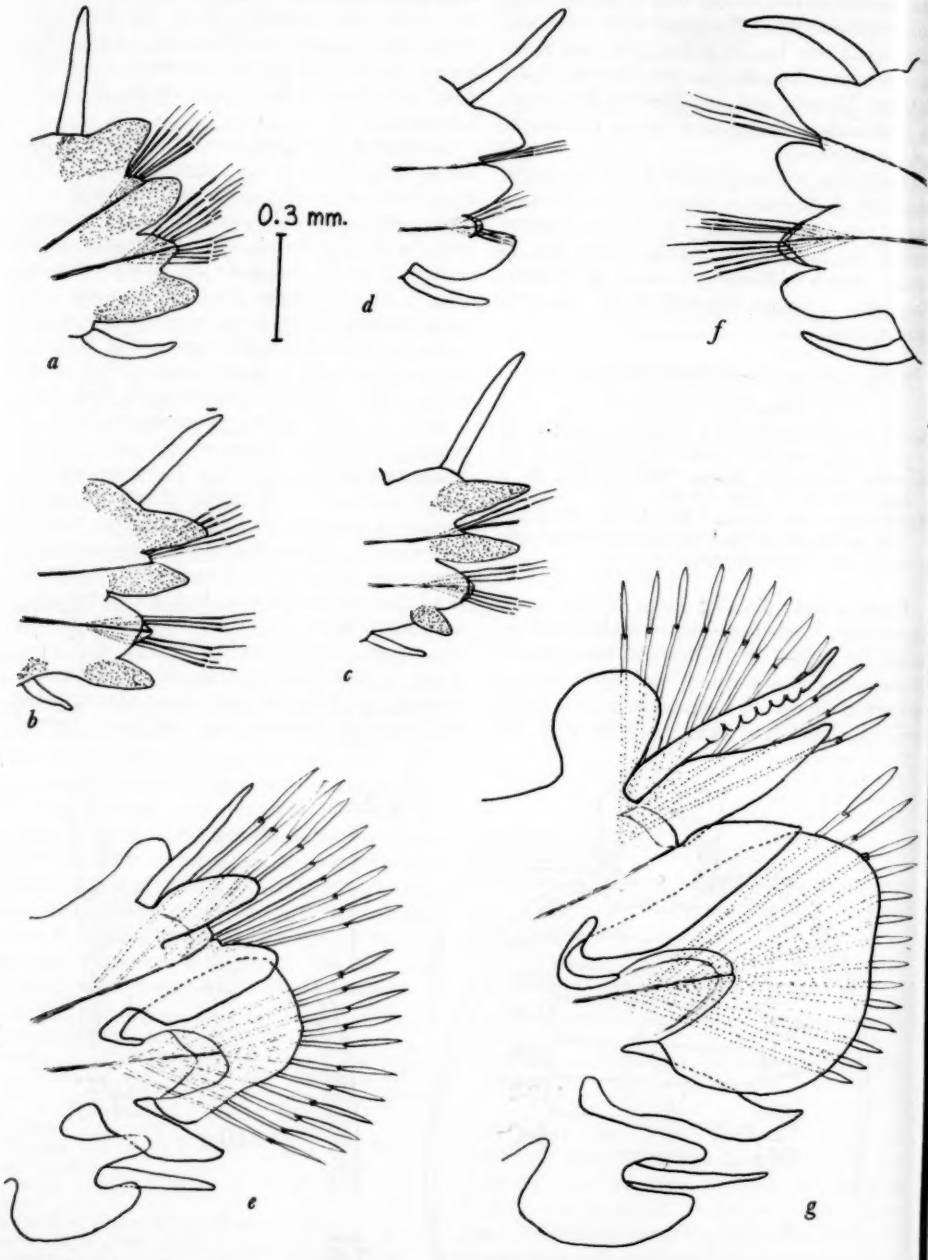

FIG. 8.—*Nereis occidentalis: a*, Parapodium from anterior region of atokous specimen; *b*, same, from middle region; *c*, same, from posterior region; *d*, parapodium from anterior region of female heteronereid; *e*, same, from posterior modified region; *f*, parapodium from anterior region of male heteronereid; *g*, same, from posterior modified region. (All parapodia drawn to same scale.)

gomph falcigers with rather short blades with recurved tip and spinous edge (Fig. 7, *b*). Acicula black. Proboscis with dark amber-colored jaws, each with 7–8 teeth; paragnaths conical, dark, those of maxillary ring smaller than those of oral ring, arranged as follows: area I, 1–4 (8–12 small ones in var. *oligohalina*); area II, crescent-shaped area of 2 rows; area III, elliptical group of 4–5 rows; area IV, arched group of 3–4 rows; area V, 0 (rarely 1, in var. *oligohalina*); area VI, usually 4 (3–6); areas VII–VIII, continuous, 2–3 rows, subequal, do not get smaller basally. Color (in alcohol): Dusky on prostomium, especially on area in front of eyes, and on some of the anterior body segments.

Description of the male and female heteronereids.—Body divided into two regions in the male: anterior region with unmodified segments, posterior region with modified parapodia with swimming setae and lamellae instead of ligules; in addition in the female, there is a short posterior or "tail" region of unmodified segments. Anterior part of prostomium (Fig. 7, *a*) may or may not be bent ventrally, thus the frontal antennae and palps may be only partially visible dorsally; eyes large, bulging (not as much as in some species of nereids). Parapodia of anterior unmodified region similar to atokous form (Fig. 8, *d*, *f*). In life, they were described as bright red in color and active swimmers. The male and female heteronereids differ in the following:

	Male heteronereid	*Female heteronereid*
Length	Up to 30 mm.	Up to 23 mm
Width	Up to 3 mm in anterior region; up to 4 mm in modified region.	Up to 2 mm in anterior region; up to 3 mm in modified region.
Number of setigers in anterior unmodified region	16	25
Number of setigers in posterior region	About 75	About 50, plus 15 in "tail"
Total number of setigers	About 90	About 90
Tentacular cirri	Longest reach setigers 4–6	Longest reach setiger 10
Anterior dorsal cirri	First 7–8 pairs clubbed.	First 5 pairs clubbed.
Anterior ventral cirri	First 5 pairs clubbed.	Same
Posterior end	Anal segment a papillated disk, with double row of numerous papillae, with or without pair of long anal cirri (may be broken off).	Anal segment bulbous, slightly crenulate, with anal cirri missing.
Color (in alcohol)	Pigmented dusky area on prostomium anterior to eyes; slight amount on anterior segments.	Same on prostomium; anterior half of anterior unmodified region darkly pigmented (fig. 7, *a*)
Parapodium of modified region	Fig. 8, *g*	Fig. 8, *e*
	Dorsal cirri crenulate with few large crenulations.	Dorsal cirri smooth, not crenulate.
	Rounded lamella above dorsal cirrus.	Elongated lamella above dorsal cirrus.
	Digitiform notopodial lamella below dorsal cirrus.	Same, shorter.
	Subacicular digitiform notopodial lamella.	Same.
	Large rounded postsetal lamella.	Same, smaller.
	Elongated digitiform lower neuropodial lamella.	Same.
	Elongated lamella above and rounded lamella below ventral cirrus.	Same.

Biology.—*Nereis occidentalis* is found intertidally and dredged in shallow depths. It is found on mud flats and sandy shoals, among ascidian and sponge masses, tube masses of maldanids, as *Petaloproctus*, oyster clusters and between shells of mussels, as *Mytilus*; it is found on piles, scrapings from floating buoys, and washed from sea weeds. The species evidently has a wide salinity tolerance, as it has been found in estuaries along with *Nereis succinea* (Frey and Leuckart). Epitokes have been found swarming at the surface in April in Texas (Corpus Christi, April 29, 1950, Hartman, 1951; Laguna Madre, April 15, 1956, collected by J. P. Breuer); early epitokes have been found in North Carolina in June (Beaufort, Hartman, 1945).

Records.—North Carolina (Beaufort), Florida (Port St. Joe, Gullport), Louisiana (Grand Isle), Texas (Corpus Christi, Laguna Madre), Mexico (Veracruz, Tecolutla), Porto Rico (Arroyo, Ensenada Honda, Culebra).

Distribution.—West Indies (Porto Rico), North Carolina, Gulf of Mexico (Florida to Mexico). In low water and shallow waters; sexual epitokes at surface.

REFERENCES

BEHRE, E. *Annotated list of the fauna of the Grand Isle region.* Occ. Pap. Mar. Lab. Louisiana State Univ., no. 6: 66 pp. 1950.

EHLERS, E. *Report on the annelids of the dredging expedition of the U.S. Coast Survey steamer* Blake. Mem. Mus. Comp. Zool. **15:** 335 pp., 60 pls. 1887.

HARTMAN, O. *The marine annelids of North*

Carolina. Bull. Duke Univ. Mar. Stat., no. 2: 51 pp., 10 pls. 1945.

———. *The littoral marine annelids of the Gulf of Mexico*. Publ. Inst. Mar. Sci. **2**(1): 7–124, 27 pls. 1951.

———. *Polychaetous annelids erected by Treadwell, 1891 to 1948, together with a brief chronology*. Bull. Amer. Mus. Nat. Hist. **109**(2): 243–310. 1956.

HORST, R. *Polychaeta errantia of the* Siboga *Expedition*. Pt. 3: *Nereidae and Hesionidae*. Siboga-Exped. **99** (Monogr. 24, 1c): 145–198, 7 pls. 1924.

RIOJA, E. *Estudios Anelidologicos. XV. Nereidos de agua salobre de los esteros del litoral del Golfo de Mexico*. Anal. Inst. Biol. México **17**: 205–214, 2 pls. 1946.

TREADWELL, A. L. *Polychaetous annelids, collected by the Barbados-Antigua Expedition from the University of Iowa in 1918*. Univ. Iowa Stud. **10**(4): 23 pp., 2 pls. 1924.

———. *New species of polychaetous annelids from California, Mexico, Porto Rico, and Jamaica*. Amer. Mus. Nov. no. 482: 7 pp., 21 figs. 1931.

———. *Polychaetous annelids of Porto Rico and vicinity*. Sci. Surv. Porto Rico and the Virgin Islands, New York Acad. Sci., **16**(2): 151–318, 118 figs. 1939.

WEBSTER, H. E. *The Annelida Chaetopoda of New Jersey*. Ann. Rep. New York Mus. Nat. Hist., no. 32: 101–128. 1880.

———. *The Annelida Chaetopoda of New Jersey*. Ann. Rep. New York Mus. Nat. Hist., no. 39: 128–159, pls. 4–10. 1886.

WEBSTER, H. E., and BENEDICT, J. *The Annelida Chaetopoda from Provincetown and Wellfleet, Massachusetts*. Rep. Comm. Fish and Fisheries for 1881: 699–747, 8 pls. 1884.

LOW TEMPERATURE STORAGE OF FREE RADICALS

The National Bureau of Standards has developed a technique for capturing and storing large numbers of highly reactive molecular fragments at temperatures near absolute zero. By this method unstable atoms and free radicals, known to exist but momentarily in flames and hot gases, are produced in an electric discharge, frozen into immobility, and trapped in solid form. Because these atoms are frozen in the excited state, they can be conveniently studied by optical spectroscopy.

In experiments to date the Bureau has produced solids containing atomic nitrogen and oxygen, and possibly atomic hydrogen and an unstable hydroxy (OH) molecule. These solids have very unusual properties, emitting bright glows, blue "flames," and colored flashes of light. When warmed 20° or 30°, they combine very actively, relasing large quantities of stored energy, principally as heat. Other possible fields of application include solid state physics and basic chemistry. Here the trapped atoms could be used as powerful probes into the solids containing them. From a study of their properties, information could be obtained about the arrangement of the atoms and molecules in the solid and about the forces acting on them. Similarly the mechanism of diffusion of atoms and of reactions between atoms and molecules could be studied.

These experiments were begun at NBS in 1954 by H. P. Broida and J. R. Pellam[1] and are being continued by H. P. Broida, A. Bass, and O. Lutes[2] of the Bureau's temperature measurements laboratory. C. M. Herzfeld of NBS is carrying out theoretical investigations[3] on the systems. The research is supported chiefly by the Office of Naval Research and the U. S. Air Force through the Office of Scientific Research of the Air Research and Development Command.

Within the last five years several methods have been developed in other laboratories for stabilizing free radicals at low temperatures. However, the present technique has the advantage that the free radicals are stored in highly excited states as a result of the electric discharge, making it possible to study and analyze them by spectroscopic techniques. Also, since the radicals are collected at much lower temperatures than in previous methods, they can be stored longer in the uncombined form.

In this method gases containing molecules

[1] BROIDA, H. P., and PELLAM, J. R., Phys. Rev. **95**: 845, 1954; BROIDA, H. P., and PELLAM, J. R., Journ. Chem. Phys. **23**: 409, 1955.

[2] BASS, A. M., and BROIDA, H. P., Phys. Rev. **101**: 1740, 1956; BROIDA, H. P., and LUTES, O. S., Journ. Chem. Phys. **24**: 484, 1956.

[3] HERZFELD, C. M., and BROIDA, H. P., Phys. Rev. **101**: 606, 1955.

of nitrogen, hydrogen, oxygen, or water are first passed through a high-frequency electric discharge, then frozen very suddenly at 4.2°K, just a few degrees above absolute zero.

The discharge is maintained in a waveguide resonator by a 2450-Mc power supply. From the resonator, a glass tube leads the resulting molecular fragments into an evacuated metal vessel containing a cold surface in contact with a liquid helium bath. To prevent solidification of the discharge products at temperatures above 4.2°K, the gases are carried to the cold surface through a passageway that is kept near room temperature by contact with warm helium gas. When the gases reach the cold surface, they freeze into solid form there.

Various techniques can then be used to study the resulting solids. Through windows in the metal vessel, a number of spectrographs of different types can be aimed at the cold surface, and the light given off by the solids frozen on the surface can be analyzed. To study the light absorbed by the solids, the gases are condensed on a transparent cold surface, and light is passed through the windows of the vessel, the condensed material, the cold surface, and finally into the spectroscopes. To determine the heat evolved by recombination of atoms, the gases are condensed into a small, simple low-temperature calorimeter, and the heat evolved by the material as it warms up is measured.

Because the free radicals produced by this method can be kept unchanged for many hours, a more detailed study of their properties has been possible than in previous work. For example, during the discharge through nitrogen the condensed solid emits a bright green glow, which tends to become yellow at high flow rates. The spectra obtained from this glow show that the structure of the solid condensed from the discharge differs from that of ordinary solid nitrogen. In fact, each atom of the condensed nitrogen forms a very loosely bound complex with some neighboring molecule, and this complex has properties that differ from those of the separate atom and molecule. The evidence shows that the complex is a definite unit. By analyzing its spectra, the forces holding it together can be studied.

Brilliant blue flashes are also observed from the solid surface during the nitrogen discharge. These flashes are thought to be due to local warming. After the flow of nitrogen is stopped, the discharge goes out and a green afterglow from the cold collected material persists for several minutes, decaying with a half-life of about 15 seconds. When the green afterglow has disappeared, sudden warming of the vessel walls (to between 25° and 35°K) causes a blue "flame" which appears to "burn" through the condensed material. The light and heat thus given off are evidently due to recombination of the atoms into molecules. When the light is analyzed spectroscopically, it gives information about the structure of the molecule just formed and about the forces acting between two atoms. The reaction of a nitrogen atom with an oxygen atom can also be studied in this way.

When oxygen is passed through the discharge, a clear, glassy deposit is obtained which has rather complex absorption spectra. Upon warming this material to about 20°K, the original deposit evaporates and a solid violet material condenses on the surface. This substance has been identified as a mixture of oxygen and ozone. Further warming of the violet substance produces ozone in large quantities. Initiation of chemical reactions in this way, by warming the frozen material, indicates the possibility of opening up a new field of very low temperature chemistry. Because of the high chemical activity of the free radicals, new chemical compounds might be formed by this process.

Low-temperature condensates have also been obtained from hydrogen and water. While the solids formed show complex behavior similar to that of nitrogen and oxygen, the results are still incompletely understood.

One science only will one genius fit,
So vast is art, so narrow human wit.
—POPE

NEMATOLOGY.—Paratylenchus projectus, *new species* (*Nematoda, Criconematidae*), *with a key to the species of* Paratylenchus.[1]

W. R. JENKINS, University of Maryland. (Communicated by R. Bamford.)

(Received July 11, 1956)

In July 1955, root and soil samples were collected from a pasture in Prince Georges County, Md., in an effort to determine the cause of stunted growth and general decline of grasses in this field. Examination revealed that a new species of *Paratylenchus* was present in large numbers.

To determine parasitism, specimens of this species were transferred to pots containing plants of tall fescue, *Festuca elatior* var. Kentucky 31, which were maintained under greenhouse conditions. Since the field under examination was used from time to time for growing tobacco, seedlings of *Nicotiana tabacum* L. were also inoculated with specimens of *Paratylenchus* n. sp. Both tall fescue and tobacco supported large population increases under these conditions.

It is probable that decline and failure of this pasture is due, at least in part, to *Paratylenchus* n. sp. Therefore, investigations are being conducted to determine pathogenic effects of this nematode on grasses and tobacco.

Paratylenchus projectus, n. sp.

Fig. 1

25 females: 373.0μ (289–475μ); a = 18.7 (15.6–20.8); b = 4.0 (3.5–4.9); c = 15.4 (11.3–19.5); V = 84.3 per cent (82.6–86.9 per cent); stylet = 31.8μ (24.8–37.1μ).

Males: Unknown.

Female.—The cuticle is marked by rather fine transverse striae about one micron apart. The lateral field occupies about two-fifths of the body diameter and is marked by four evenly-spaced incisures. The slightly-offset lip region is truncate with a median labial extension and is marked by three transverse striations. Neither amphids nor cervical papillae have been observed; however, phasmids are located in the lateral field anterior to the anus. The conspicuous excretory pore varies in its location from just behind the median swelling of the esophagus to the anterior end of the basal swelling of the esophagus, always on the ventral surface. There is an average of 50 postvulval annulations.

The buccal cavity is small and there is no sclerotized cephalic framework. The spear averages 31.8 microns and has prominent knobs which are somewhat flattened on the anterior surface. The dorsal esophageal gland opens into the lumen of the esophagus about one-fifth the spear-length behind the base of the spear. There is a typically criconematoid median bulb with a valvular apparatus behind which the duct of the ventral esophageal glands opens into the lumen of the esophagus. Posterior to the median bulb, there is a long and narrow isthmus about which lies the circumesophageal nerve ring. The terminal swelling of the esophagus is somewhat pyriform in shape. There is no cardia. The intestine, the cells of which are filled with many small, refractive inclusions, ends in a short rectum and obscure anus.

There is a single outstretched ovary which usually reaches to the anterior end of the intestine but has been observed as far anterior as the median esophageal bulb. The cap cell gives rise to several oogonia which are arranged in a double line. Only one egg, averaging 57.9μ by 13.2μ, was observed in the uterus at a time. The vulva is an anteriorly sloping, transverse slit flanked by lateral vulval membranes. No spermatheca or postvulval uterine sac has been observed. There is a marked reduction in body diameter immediately behind the vulva.

Larvae were observed to have a small and indistinct esophagus. The median swelling was much reduced in size but did possess a large valvular apparatus.

The normal relaxed position was a ventral curving in both larvae and females.

Type host.—Soil about roots of pasture grass.

Type locality.—Upper Marlboro, Prince Georges County, Md.

Diagnosis.—The absence of males distinguishes *P. projectus* from *P. goodeyi* Oostenbrink, 1953, *P. hamatus* Thorne and Allen, 1950, *P. besoekianus* Bally and Reydon, 1931, *P. elachistus*

[1] Scientific Article no. *A571*, Contribution no. *2729*, of the University of Maryland Agriculture Experiment Station, Department of Botany.

Steiner, 1942, *P. minutus* Linford, 1949, *P. macrophallus* (de Man, 1880) Goodey, 1934, and *P. dianthus* Jenkins and Taylor, 1956.

This species differs in many ways from females of species in which no males have been reported. From *P. bukowinensis* Micoletzky, 1922, *P. projectus* can be distinguished by its slightly offset lip region which is truncated and bears three striations, in its lack of a post-vulval uterine sac, lateral vulval wings, and in the shape of the spear knobs.

P. projectus differs from both *P. nanus* Cobb,

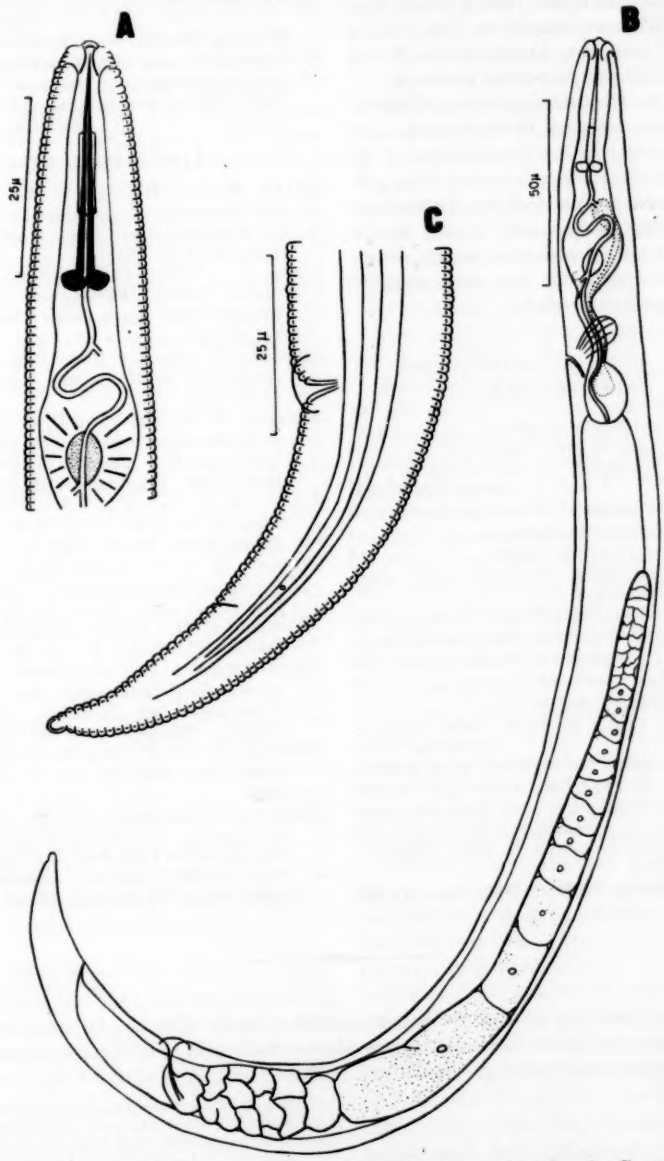

FIG. 1.—*Paratylenchus projectus*, n. sp.: A, Anterior portion; B, mature female; C, posterior portion.

1923 and *P. anceps* Cobb, 1923 in its offset, striated lip-region, its smaller spear which bears flattened knobs, and in its lack of a spermatheca. It differs further from *P. anceps* by having four incisures in the lateral field, while the latter has only two incisures.

P. curvitata van der Linde, 1938, is smaller than *P. projectus* (330μ as opposed to 373μ), has a much smaller spear (24μ as opposed to 31.8μ), and does not bear a median labial extension.

Because of the frequent occurrence of *Paratylenchus* species in soil about roots of plants, a key is presented to aid in the identification of described species. This key was devised from published descriptions and illustrations, not from personal examination of specimens of each species. It is based for the most part on female characteristics, because males are frequently unknown or exist in very small numbers.

KEY TO SPECIES OF PARATYLENCHUS MICOLETZKY, 1922

1. Lip region a truncated cone.....2
   Lip region smooth and rounded.....8
2. Lateral field marked by two incisures
   anceps Cobb, 1923
   Lateral field marked by four incisures.....3
3. Postvulval uterine sac present.....4
   Postvulval uterine sac absent.....5
4. Female spear about 19μ long; male spear faded and indistinct
   besoekianus Bally and Reydon, 1931
   Female spear about 25μ long; males absent
   bukowinensis Micoletzky, 1922
5. Lateral vulval membranes present.....6
   Lateral vulval membranes absent.....7
6. Female lip region striated; males absent
   projectus, n. sp.
   Female lip region not striated; males present
   dianthus Jenkins and Taylor, 1956
7. Postvulval reduction in body diameter; males absent.....*curvitata* van der Linde, 1938
   No postvulval reduction in body diameter; males frequent
   macrophallus (deMan, 1880) Goodey, 1934
8. Females stout, spear 48–56μ
   goodeyi Oostenbrink, 1953
   Females typically slender.....9
9. No marked postvulval reduction in body diameter....*hamatus* Thorne and Allen, 1950
   Marked postvulval reduction in body diameter 10
10. Females 360–410μ long; males absent
    nanus Cobb, 1923
    Females 234–310μ long; males frequent.....11
11. Male with anal sheath surrounding spicula, tail convex-conoid....*minutus* Linford, 1949
    Male without anal sheath, tail short and subacute.....*elachistus* Steiner, 1942

LITERATURE CITED

BALLY, W., and REYDON, G. A. *De tegenwoordige stand van het vraagstuk van de wortelaaltjes in de koffiecultuur*. Arch. Koffiecult. Nederl. Indie **5**: 92–94. 1931.

COBB, N. A. *Notes on* Paratylenchus, *a genus of nemas*. Journ. Washington Acad. Sci. **13**: 254–257. 1923. Also: Contr. Sci. Nematology **14**: 367–370.

GOODEY, T. *Observations of* Paratylenchus macrophallus (*de Man, 1800*). Journ. Helm. **12**: 79–88. 1934.

JENKINS, W. R., and TAYLOR, D. P. Paratylenchus dianthus, *new species* (*Nematoda, Criconematidae*), *a parasite of carnation*. Proc. Helm. Soc. Washington **23**: 124–127. 1956.

LINDE, W. J. VAN DER. *A contribution to the study of nematodes*. Ent. Mem. Union South Africa **2**: 25, 26, 34. 1938.

LINFORD, M. B., OLIVEIRA, J. M. and MAMORU, I. Paratylenchus minutus, *n. sp., a nematode parasitic on roots*. Pacific Sci. **3**: 111–119. 1949.

MICOLETZKY, H. *Die freilebenden Erd-Nematoden*. Arch. Naturg., Abt. A, **87**: 605–607. 1922.

OOSTENBRINK, I. M. *A note on* Paratylenchus *in the Netherlands with the description of* P. goodeyi *n. sp.* (*Nematoda, Criconematidae*). Tijdsch. Plantenziekten **59**: 207–216. 1953.

STEINER, G. *Plant nematodes the grower should know*. Proc. Soil Sci. Soc. Florida **4B** 37–39. 1942.

THORNE, G., and ALLEN, M. W. Paratylenchus hamatus *n. sp. and* Xiphinema index *n. sp., two nematodes associated with fig roots, with a note on* Paratylenchus anceps *Cobb*. Proc. Helm. Soc. Washington **17**: 27–35. 1950.

The generality of men are so accustomed to judge of things by their senses that because air is invisible they ascribe but little to it, and think of it as but one remove from nothing.—R. BOYLE (1673)

PHYSIOLOGY.—*Effect of sympathetic denervation of the urinary bladder in animals and man.*[1] E. H. INGERSOLL, L. L. JONES, and E. S. HEGRE, Medical College of Virginia. (Communicated by Paul H. Oehser.)

The reaction of the urinary bladder to denervation in the laboratory animal has been extensively reported, especially in the older literature, but it has been only in recent years that careful studies have been published in man. In fact, as Heimburger et al. (*1*) have pointed out, knowledge of the human bladder innervation has been taken largely from comparisons with experimental animals and from human dissections. In this study we will review the response of the viscus to division of the sympathetic outflow, first in animals and then in man.

Effect in the cat.—There is much difference of opinion as to the effect of section of the sympathetic fibers to the bladder, not only in the cat, but in other animals and in man as well. Neither Beattie (*2*) nor Nawrocki and Skabitschewsky (*3*) observed any change in bladder function following section of the hypogastric nerves in the cat. Some workers (*4, 5, 6, 7*) found that division of the sympathetics did not interfere with bladder emptying but seemed to increase temporarily the frequency of micturition.

Elliott (*8*), in addition to observing increased frequency of bladder emptying, noted that the tone of the viscus was permanently increased following section of the sympathetic outflow. He observed that this tone was diminished only slightly by further section of the pelvic nerves. Similarly, Langworthy et al. (*9, 10, 11*) found an immediate decrease in vesical volume when the post ganglionic sympathetic fibers were cut on one side. This defect persisted for several weeks. Removal of the sympathetics on both sides, according to Langworthy, produced a more marked and lasting decrease in volume.

These findings have been difficult to correlate with what has been observed following electrical stimulation of the hypogastric nerves in the cat. We (*12, 13*) have shown, as have others, that excitation of the sympathetic outflow to the bladder regularly evoked contractions of all portions of the detrusor muscle. True, this response was not a sustained one, lasting only a few seconds, and it was invariably followed by relaxation. It may be possible, as Gillilan (*14*) has suggested, that sympathetic fibers play a minor role in micturition, and only come into play in emergencies. However, the observed increase in frequency of micturition, together with the decrease in vesical size after sympathetic denervation, would tend to support the views of those who believe that the hypogastrics are not only the "filling" nerves of the bladder but are antagonistic in action to the parasympathic outflow (*8, 15, 16, 17, 18, 19, 20, 21*).

Effect in the dog.—Most investigators (*2, 22, 23, 24, 25, 26*) have found that section of the hypogastric nerves in the dog caused no interference with normal micturition. A few, such as Creevy (*7*), and Jacobson (*27*), have noted changes in vesical function after division of sympathetic nerves to the bladder. Removal of the hypogastrics, according to Creevy, produced a slight, transitory increase in frequency of micturition while Jacobson observed a prompt increase in vesical tone and an equally prompt decrease in bladder capacity. The vesical tone in Jacobson's dogs gradually decreased but never entirely returned to normal; functionally, however, he was unable to distinguish this type of preparation from the normal bladder as the ability to void was in no way impaired by the operation.

Effect in man.—Section of the hypogastric nerves in man at first was done on the premise (*28*) that the internal sphincter of the bladder had its motor innervation through the sympathetic nervous system, and that it became hypertonic owing to the imbalance caused by the removal of the parasympathetic inhibition. One of the difficulties with this theory has been that no conclusive evidence has ever been forthcoming to prove that the internal sphincter was innervated any differently than the re-

[1] This investigation was supported in part by research grant B-704 from the National Institute of Neurological Diseases and Blindness, National Institutes of Health, Public Health Service.

mainder of the detrusor muscle (*29*). Nevertheless, support was given to the theory of the antagonistic action of the two systems by Learmonth's investigations in man. In a series of papers (*20*, *30*, *31*) he reported that, following presacral neurectomy, both the muscles of the trigone and the internal sphincter relaxed. Learmonth concluded from his studies that sympathetic influences act as a continuous brake on contractions of the detrusor and, that following lesions of the sacral nerves, presacral neurectomy aided in the restoration of the functioning automatic bladder.

Other workers (*32*, *33*, *34*, *35*, *36*), too, have reported beneficial results from sympathetic denervation of the bladder in cases of neurogenic vesical dysfunction. In paraplegic patients with cervical or upper thoracic spinal cord injuries, anterior rhizotomy of the lower thoracic through the first sacral roots resulted in an increased bladder capacity (*37*). Likewise, Kuhn (*38*) reported that section of the same anterior spinal nerve roots in patients with hypertonic bladders reduced detrusor activity sufficiently to reclassify the bladders to that of the reflex type.[2]

Van Duzen (*40*), on the other hand, believed that presacral neurectomy was definitely harmful to the patient. Within a period of two months after the operation evidence of urinary retention, paralysis of the trigone muscles, and a spastic internal sphincter appeared.

Most investigators (*1*, *2*, *10*, *14*, *28*, *41*, *42*, *43*, *44*, *45*, *46*) have concluded that sympathetic denervation of the bladder has no effect in man, either on micturition or on any other bladder activity. They have discarded the idea that there is an antagonistic action between the two divisions of the autonomic nervous system and have decided that the parasympathetic components are the only ones that have any real influence on bladder function.

REFERENCES

(1) HEIMBURGER, R. F., FREEMAN, L. W., and WILDE, N. J. Journ. Neurosurg. **5:** 154. 1948.

(2) BEATTIE, J. Canad. Med. Assoc. Journ. **23:** 71. 1930.

(3) NAWROCKI, F., and SKABITSCHEWSKY, B. Arch. Ges. Physiol. **48:** 335. 1891.

(4) BARRINGTON, F. J. F. Quart. Journ. Exp. Physiol. **9:** 261. 1915.

(5) ———. Ibid. **8:** 33. 1915.

(6) ———. Proc. Roy. Soc. Med. **25:** 557. 1931.

(7) CREEVY, C. D. Arch. Neurol. and Psychiat. **34:** 777. 1935.

(8) ELLIOTT, T. R. Journ. Physiol. **35:** 367. 1907.

(9) LANGWORTHY, O. R., and KOLB, L. C. Anat. Rec. **71:** 249. 1938.

(10) LANGWORTHY, O. R., and MURPHY, E. L. Journ. Comp. Neurol. **71:** 487. 1939.

(11) LANGWORTHY, O. R., REEVES, D. L., and TAUBER, E. S. Brain **57:** 266. 1934.

(12) HEGRE, E. S., and INGERSOLL, E. H. Journ. Urol. **61:** 1037. 1949.

(13) INGERSOLL, E. H., JONES, L. L., and HEGRE, E. S. Journ. Urol., **72:** 178. 1954.

(14) GILLILAN, L. A. *Clinical aspects of the autonomic nervous system.* Boston, 1954.

(15) ALPERS, B. J. *Clinical neurology*, 2d ed. Philadelphia, 1950.

(16) COURTADE, D., and GUYON, J. F. Comp. Rend. Soc. Biol. **10:** 618. 1895.

(17) ———. Arch. Physiol. Norm. et Path. **8:** 622. 1896.

(18) FERNSIDES, E. G. Brain **40:** 149. 1917.

(19) LANGLEY, J. N. Journ. Physiol. **27:** 237. 1901.

(20) LEARMONTH, J. R. Brain **54:** 147. 1931.

(21) STRONG, O. S., and ELWYN, A. *Human neuroanatomy*, 3d ed. Baltimore, 1953.

(22) LANGLEY, L. L., and WHITESIDE, J. A. Fed. Proc. **9:** 74. 1950.

(23) ———. Journ. Neurophysiol. **14:** 147. 1951.

(24) LANNEGRACE, M. Comp. Rend. Acad. Sci. **114:** 789. 1892.

(25) MCCAUGHAN, J. M., and HERSHEY, J. H. Journ. Missouri State Med. Assoc. **31:** 417. 1934.

(26) MOSSO, A., and PELLACANI, P. Arch. Ital. Biol. **1:** 97. 1882.

(27) JACOBSON, C. E. Journ. Urol. **53:** 670. 1945.

(28) NESBIT, R. M., and GORDON, W. G. Journ. Amer. Med. Assoc. **117:** 1935. 1941.

(29) MCCREA, E. D., and MACDONALD, A. D. Brit. Journ. Urol. **6:** 119. 1934.

(30) LEARMONTH, J. R. Proc. Roy. Soc. Med., Pt. 1, **25:** 552. 1931.

(31) LEARMONTH, J. R., and BRAASCH, W. F. Surg. Gynec. and Obst. **51:** 494. 1930.

(32) CHEETHAM, J. G. Journ. Urol. **37:** 148. 1937.

(33) DAVIS, A. A. Brit. Med. Journ. **2:** 1, 1934.

(34) HUGGINS, C., WALKER, A. E., and NOONAN, W. T. Jour. Urol. **41:** 696. 1939.

(35) MUNRO, D. New England Journ. Med. **233:** 453. 1945.

(36) PEARL, F. L., and STRAUS, B. Journ. Urol. **39:** 645. 1938.

(37) FREEMAN, L. W., and HEIMBURGER, R. F. Journ. Neurosurg. **4:** 435. 1947.

[2] The first sacral nerve contributes few, if any, motor fibers to the urinary bladder (*39*).

(38) KUHN, R. A. Journ. Neurosurg. **6:** 320. 1949.
(39) INGERSOLL, E. H., JONES, L. L., and HEGRE, E. S. Virginia Med. Month. **83:** 23. 1956.
(40) VAN DUZEN, R. E. South. Med. Journ. **25:** 964. 1932.
(41) DENNY-BROWN, D. E. New England Journ. Med. **215:** 647. 1936.
(42) EMMETT, J. L. Proc. Staff Meeting Mayo Clin. **21:** 102. 1946.
(43) LANGWORTHY, O. R., KOLB, L. C., and LEWIS, L. G. Physiology of micturition. Baltimore, 1940.
(44) MARSHALL, S. F., and KENNEDY, R. J. Surg. Clin. North America **25:** 518. 1945.
(45) MEIROWSKY, A. M., ARNOLD, M., SCHEIBERT, C. D., and HINCHEY, T. R. Journ. Neurosurg. **7:** 33. 1950.
(46) VORIS, H. C., and LANDES, H. E. Arch. Neurol. and Psychiat. **44:** 118. 1940.

ACADEMY MEMBERS RECEIVE HONORS

Dr. Richard K. Cook, National Bureau of Standards, formerly senior editor of this JOURNAL, has been elected President of the Acoustical Society of America for the term 1957–58. Dr. Cook's work in the physics of sound is nationally known. He is currently spending a year's leave of absence from NBS to conduct research at the Bell Telephone Laboratories.

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Dr. Ladislaus L. Marton, of the National Bureau of Standards and WAS, has been elected to the Royal Academy of Belgium in recognition of his contributions to science. Dr. Marton will fill the vacancy left by the Dutch physicist, J. Verschaffelt, who died last year. He will be the only American physicist among the foreign members of the Academy.

The Royal Academy of Belgium recognizes outstanding achievement in science, literature, the arts, and other fields. Membership is limited to 90 regular members, 150 foreign members, and 30 correspondents. The Division of Sciences, to which Dr. Marton was elected, has 15 regular members, 5 correspondents, and 25 foreign members.

Dr. Marton has received international recognition for his work in electron optics, particularly relative to the development of the electron microscope. He is chief of the Electron Physics Section of the Atomic and Radiation Physics Division at the Bureau. This section does research on various aspects of the physics of the free electron. The work includes electron scattering in solids, electron interference, electron polarization, electron optics, and applications of some of these phenomena to other measuring techniques.

* * * * *

Dr. Francis B. Silsbee, chief of the Electricity and Electronics Division at the National Bureau of Standards, has been awarded the Department of Commerce Gold Medal for Exceptional Service. The award recognizes his "outstanding contributions to the fields of electricity, electrical engineering, and electrical measurement."

Since 1946 Dr. Silsbee has directed the Bureau work in electricity, which concerns the development, improvement, and dissemination of the standards of measurement for electrical quantities and the study of properties of materials that are important in electricity and magnetism. In 1954 the Bureau's basic electronic research and development programs were placed under his direction.

Dr. Silsbee's work in his 45 years at NBS has covered a wide range. In 1916, working in the newly discovered phenomenon of superconductivity at very low temperatures, he suggested a theoretical relationship between the values of critical currents and magnetic fields which is widely known today as the "Silsbee Hypothesis".

During World War I, he led NBS work on the development of spark plugs, magnetos and other aircraft ignition parts. In World War II, he was in charge of the later phases of the development of a special bomb director and guided research on the lighting hazards to nonmetallic aircraft.

Dr. Silsbee was born in Lawrence, Mass., in 1889 and received his B.S. in Electrical Engineering from Massachusetts Institute of Technology in 1910, and the following year he was awarded his master's degree there. In 1915 he received his Ph.D. in Physics from Harvard University.

He first joined the NBS staff in 1911 and was made Chief of the Electrical Instruments Section in 1939. In 1946 he was named to his present position.

He is a past president of Washington Academy of Sciences and of the Philosophical Society of Washington; a fellow of the American Physical Society, the American Institute of Electrical Engineers, and the American Association for the Advancement of Science; and has written numerous technical papers in his field.

* * * * *

Dr. Galen B. Schubauer, chief of the Fluid Mechanics Section of the Mechanics Division of the National Bureau of Standards, has been awarded the Department of Commerce Gold Medal for Exceptional Service. The award recognizes his "outstanding contributions to basic aerodynamics over the past 20 years."

Dr. Schubauer is known internationally for his contributions to the field of aerodynamics. His work on turbulence and air flow and in the development of instruments for measuring these phenomena has been vital in the development of modern high speed aircraft. Among the recent projects of Dr. Schubauer's section was a study of the accuracy of the hot-wire anemometer at speeds up to twice the speed of sound. The instrument has been basic in subsonic air speed research but it was not known whether it could be used at supersonic levels.

Born in Sparrows Point, Md., in 1904, Dr. Schubauer received his B.A. degree from Pennsylvania State College in 1928, M.S. from California Institute of Technology in 1930, and Ph.D. from John Hopkins University in 1934. He joined the NBS staff in 1929 and was made Chief of the Aerodynamics Section in 1946. In 1953 he was appointed to his present position when the Hydraulics and Aerodynamics Sections were combined.

He holds Institute of Aeronautical Sciences and Washington Academy of Science awards for his work. In addition to being a member of these two organizations Dr. Schubauer also belongs to the American Physical Society, Sigma Pi Sigma, Phi Kappa Phi, and Sigma Xi.

* * * * *

Dr. Lewis V. Judson, chief of the Length Section of the Optics and Metrology Division of the National Bureau of Standards, has been given the Department of Commerce Silver Medal for Meritorious Service. The Award recognizes Dr. Judson's "extremely competent performance for 38 years in the field of length standards and precise length determinations."

Dr. Judson is custodian of the National Standard of Length. In addition he is in charge of calibrations of measuring tapes, graduation and calibration of precision circles, research in thermal expansion of solids and interferometry in length measurements. The development of sieve specifications and calibrations; testing of haemacytometer chambers and accompanying cover glasses and surveyor's leveling rods: and calibration of many other precise measuring instruments are also under his supervision.

Dr. Judson joined the NBS staff in 1917 and was made Chief of the Length Section the following year. He is the author of some 60 articles in his field.

Born in Plainville, Conn., in 1893, Dr. Judson graduated from Clark University in 1916 and received a M.A. in physics there in the following year. He was awarded his Ph.D. in physics from Johns Hopkins University in 1925.

He is a member of the Philosophical Society of Washington, the Washington Academy of Sciences, the American Physical Society, the Optical Society of America, the American Congress of Surveying and Mapping, the American Geophysical Union, the American Society for Testing Materials, the American Association for the Advancement of Science, and the Société Francaise de Physique.

* * * * *

Dr. Herbert F. Schiefer, a textile physicist in the Organic and Fibrous Materials Division of the National Bureau of Standards, has been awarded the Department of Commerce Gold Medal for Exceptional Service. The award recognizes his "outstanding contributions to textile science and technology."

Dr. Schiefer is an internationally known authority in the textile field. In addition to his contributions at NBS, he served as technical advisor in 1950 to the Economic Cooperation Administration in Europe and in 1955 to the International Cooperation Administration in Asia. He was a delegate to the 1955 International Wool Research Conferences in Australia. In 1945 he served as scientific consultant to the Department of the Army in the first survey of the German textile industry after World War II. He took leave of absence from the Bureau in 1951–52 to serve as director of research and graduate instruction in the School of Textiles of North Carolina State College.

Dr. Schiefer has developed and invented many devices for testing the properties of fibers, yarns, and fabrics and a number are widely used by the textile industry today. He received the Harold DeWitt Smith Memorial Medal in 1950 from the American Society for Testing Materials for his pioneering work in textile research. His recent work has been concerned with new techniques for obtaining stress-strain relationships in yarns subjected to rapid impact loading and the measurment of a new basic property of textile fibers, the limiting breaking velocity. This property is of practical importance in the design of textiles for safety lines, parachute webbing, tire cord, and flexible body armor.

Dr. Schiefer came to the Bureau in 1929 from Des Moines University where he was head of the mathematics and physics department. He was educated at the University of Michigan, receiving his degree in Civil Engineering in 1924, his M.S. in Science in 1925, and a Ph.D. in astrophysics in 1928. During his last four years at Michigan he was instructor of engineering mathematics and astronomy.

Dr. Schiefer has written some 100 scientific papers and technical reports and holds three patents. He is a member of Tau Beta Pi, the Fiber Society (former president), Washington Philosophical Society, Washington Academy of Science, American Society for Testing Materials, and is a fellow of the British Textile Institute and the American Physical Society.

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Herbert C. Vacher, head of the metallographic and X-ray diffraction laboratory, at the National Bureau of Standards, has been awarded the Department of Commerce Silver Medal for Meritorious Service for his contributions to the field of metallurgy.

A NBS staff member for 30 years, Mr. Vacher has conducted important research and written a number of articles on the mechanical properties and structures of metals and alloys. He also acts as a consultant in the mechanical metallurgy laboratory on projects which involve correlating the mechanical properties with the structure of metals. Mr. Vacher's earlier work at NBS involved the determination of gases in metals and physical chemistry of gas-metal equilibria. Such information is important in the manufacture of steel.

Born in Greensberg, La., in 1901, Mr. Vacher received his E.M. degree from the Texas School of Mines in 1922 and a M.S. in metallurgy in 1926 from the University of Nevada where he studied under a Challoner Fellowship.

He is a member of the American Institute of Mining and Metallurgical Engineers, the American Society for Metals, American Crystallographic Association, and the Washington Academy of Sciences.

ODDITIES OF NATURE

Among the most curious of insects are the "bagworms," which belong to the moth family.

The bagworm is a caterpillar. The female spends her entire life in a cocoonlike silken bag into whose texture she interweaves bits of leaves from the host plant. The bag grows as the worm grows, and in local species late in summer it becomes as much as 2 inches long. The bags of some tropical species are more than 7 inches long. The female remains wingless, and the bag in which she spends her life is attached to a twig of the host plant. At the end of summer she lays within the silken sack a mass of eggs which hatch late in spring. The males metamorphose into winged insects.

Dr. Frank Morton Jones, of Wilmington, Del., has just presented to the Smithsonian Institution one of the world's outstanding collections of these insects. Sixty years were spent in assembling this collection, which consists of 4,400 specimens. Of these 1,174 are adult, winged males, 2,133 are bags showing the many forms resulting from differences in food plants, and 830 are immature forms. There are also 1,000 microscope slides of important structures of these insects.

Bagworms are nearly worldwide in distribution. In this country they are chiefly pests of ornamental trees and shrubs, and are especially destructive to arborvitae. They are preyed upon by a number of other insects. The collection includes 273 such insect-parasites.

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One of earth's most fantastic animals—the three-horned chameleon of East Africa—has just been added to the reptile collections of the Smithsonian Institution. It is sometimes described as a replica, in miniature, of the ancient monster dinosaur *Triceratops*, which has been extinct for about 75,000,000 years. The two, of course, are in no direct way related. The three-horned chameleon grows to a length exceeding 12 inches. The curious horns, an inch to an inch and a half long, protrude from the nose and between the eyes of the males. Females are hornless.

These chameleons are extremely pugnacious animals and sometimes use their horns in fights to the finish. At times the contests develop into tedious pushing matches, with the horns interlocked. At other times a really vigorous fighter will dispose of a weaker adversary in a few minutes. Males are brilliantly colored with blues, greens, and yellows. Uganda natives are terrified by the demoniacal-looking animals, which actually are harmless to man. The popular superstition is that if one happens to see one of these lizards when it is enraged and hissing the person will die in a few days. The curse of the chameleon may be partly averted, it is believed, by capturing and roasting it, and then wearing part of the burned body as a talisman. Still the unfortunate person is supposedly sure to die quite young.

The creature is most abundant in arid areas covered with low shrubs. It is an aerial acrobat and can leap as much as 2 feet from branch to branch. The chameleon has a prehensile tail, like that of various monkeys, and with the tip of this tail alone it can hang from a branch. It sits motionless for hours at a time and feeds almost exclusively on flies, butterflies, beetles, and bees which may come within reach of its darting tongue. The creature is a consummate bluffer. Apparently it never tries to hide or run when confronted with an enemy. Instead it tries to frighten the foe, including man, by inflating its body so that the otherwise loose skin is drawn taut.

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Birds that hold fencing tournaments are the big-billed toucans of Barro Colorado Island, the Smithsonian Institution's tropical preserve in Gatun Lake, Panama Canal Zone. They fence with their formidable beaks but seem careful not to hurt one another. One scientist who studied Barro Colorado's bird life described the birds as follows:

"I saw fourteen toucans scattered about in a big leafless tree in the center of the jungle. Two appeared to be fencing. They stood in one spot and fenced with their bills for a half minute or so, rested, and were at it again. Presently they flew off into the forest and then I noticed two others that had now begun to fence. Then one of these flew away, and the remaining one picked a new opponent and fell to fencing again. . . . They did not move about much while fencing, although sometimes one climbed above the other as though to gain an advantage. They fenced against each other's beaks and never seemed to strike at the body. There was a fairly rapid give and take . . . the bills clattering loudly against each other."

These fencing toucans are among the more conspicuous birds of the island, particularly because of their call—a shrill, froglike "cree," which is repeated over and over again and can be heard half a mile away. The call is most frequent in the morning and late in the afternoon, but it stops abruptly at sunset.

Simplicity is the seal of truth. Nature is wonderfully simple, and the characteristic mark of a childlike simplicity is stamped upon all that is true and noble in nature.—SENDIVOGIUS (1650)

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